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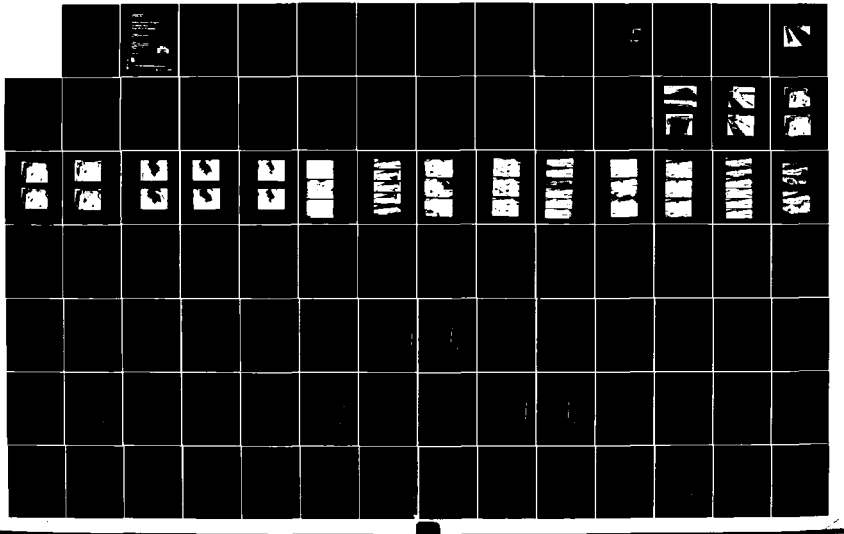

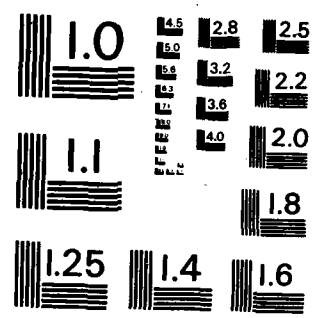

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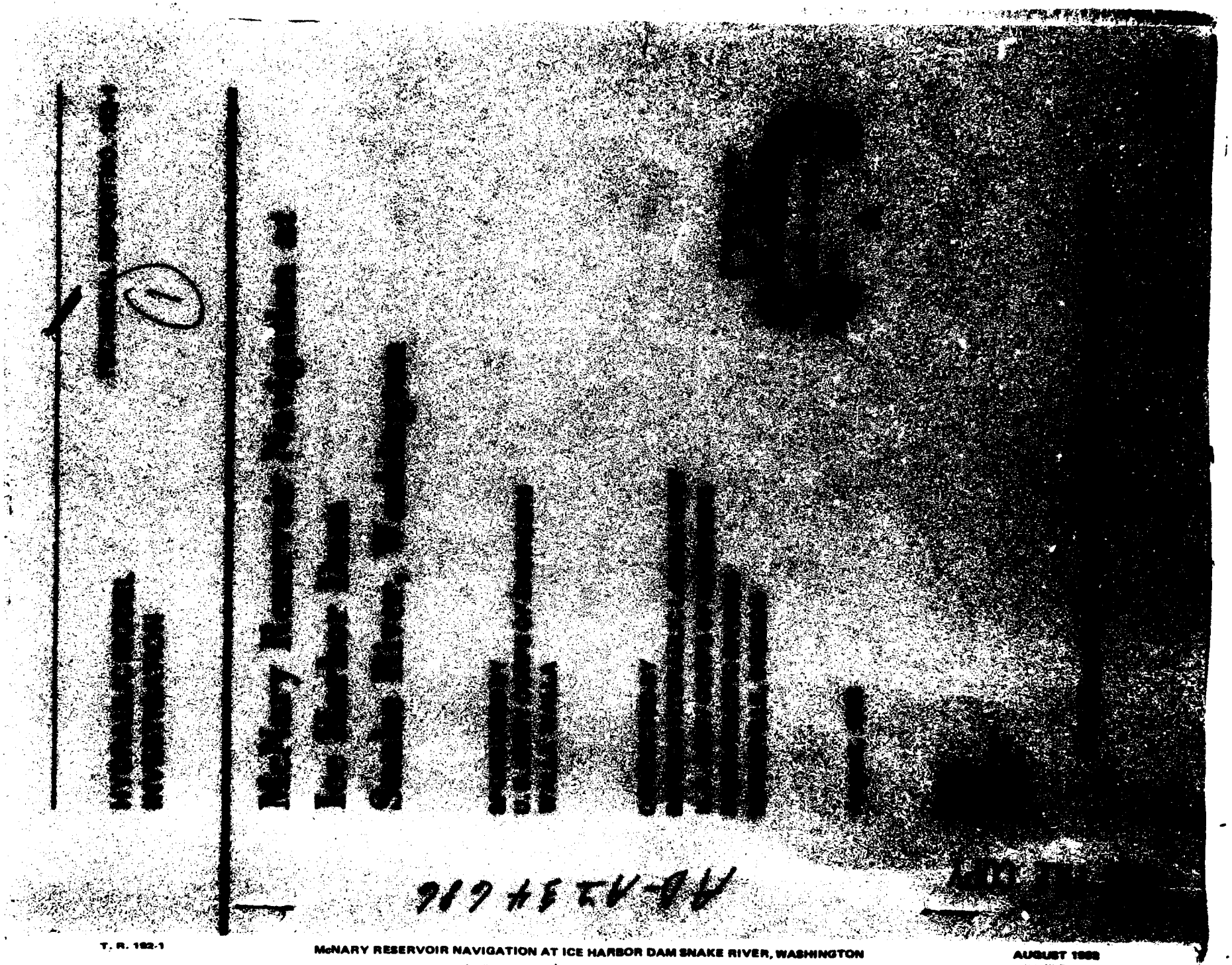

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McNARY RESERVOIR NAVIGATION AT ICE HARBOR DAM SNAKE RIVER, WASHINGTON

AUGUST 1968

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 1:100-scale model simulating the Ice Harbor Dam project and navigation channel and river downstream from the project was used to test various structural modifications in an attempt to remedy navigation problems which exist as a result of crossflow from the powerhouse. A radio-controlled scale model of a 2000-horsepower towboat with barges was used in evaluating the navigation improvements. Modifications tested included various length and geometric guide wall extensions as well as channel widening. Towboat operators assisted

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in evaluation of the modifications tested. None of the tested modifications succeeded (to the satisfaction of the tow operators) in correcting the difficulties experienced while navigating downstream from the Ice Harbor lock.

PREFACE

Physical model studies to determine the feasibility of correcting navigational problems in the McNary reservoir below Ice Harbor Dam were authorized on 1 October 1980 by the North Pacific Division at the request of the Walla Walla District (NPW), Corps of Engineers.

The studies were conducted at the North Pacific Division Hydraulic Laboratory from June 1981 to March 1982 under the supervision of P. M. Smith, Director, and R. L. Johnson, Chief of Hydraulics Branch. The studies were conducted by R. L. Johnson with assistance from R. R. Stocker. Liaison with NPW was provided by G. F. Roediger. This report was prepared by Northwest Hydraulic Consultants and the Seattle District, Corps of Engineers.

Representatives from local navigation companies — Tidewater Barge Lines, Crowley Maritime Corporation, Knappton Corporation, Western Transportation Company, and Coast Trading, and the U.S. Coast Guard -- worked together with NPW and laboratory staff engineers in an attempt to find a satisfactory method of improving conditions downstream from the lock and dam.

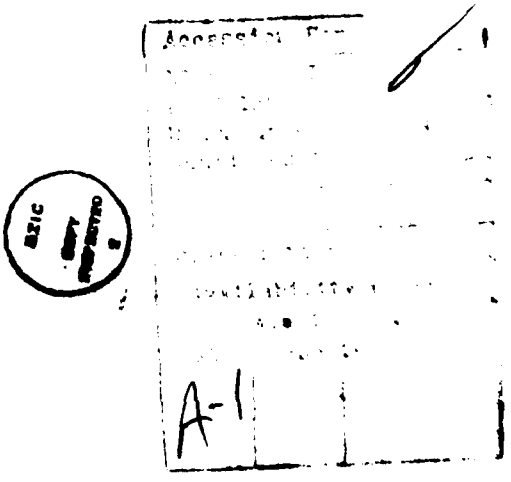

TABLE OF CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles	1.609344	kilometres
feet per second	0.3048	metres per second
cubic feet per second	0.0283168	cubic metres per second
pounds (mass)	0.4535924	kilograms
kilowatt-hours	3,600,000	joules

McNARY RESERVOIR NAVIGATION AT ICE HARBOR DAM
SNAKE RIVER, WASHINGTON
Hydraulic Model Investigations

PART I: INTRODUCTION

The Prototype

1. Ice Harbor Dam is located on the Snake river 9.7 miles* upstream from the junction of the Columbia and Snake Rivers and about 12 miles east of the city of Pasco, Washington. Figure 1 is a location map of the area. The project, which began operation in 1962, is the first of four multiple-purpose dams to be constructed on the lower Snake River by the U.S. Army Corps of Engineers for power, navigation, and other uses.

2. As shown on plate 1, principle features of the 1,788-foot-long project include a powerhouse for six 90,000-kilowatt generating units (initial installation of three units), a navigation lock, a concrete gravity-type spillway with ten 50-foot-wide bays and 52.5-foot-high tainter gates, and facilities for passing migratory fish upstream over the dam. The navigation lock has net dimensions of 86 by 675 feet and maximum single lift of 103 feet between minimum tailwater elevation 337 and normal pool elevation 440.** A 600-foot-long training wall extends from the south wall of the lock to protect navigation from the turbulent flows issuing from the powerhouse and spillway. The navigation channel downstream of the lock follows the north bank of the river as shown on plate 2 and is dredged to provide a minimum of 18 feet of water with a width of 250 feet.

Navigation Problem

3. Navigation tow operators have experienced difficulty approaching and leaving the downstream end of the lock particularly with a low pool

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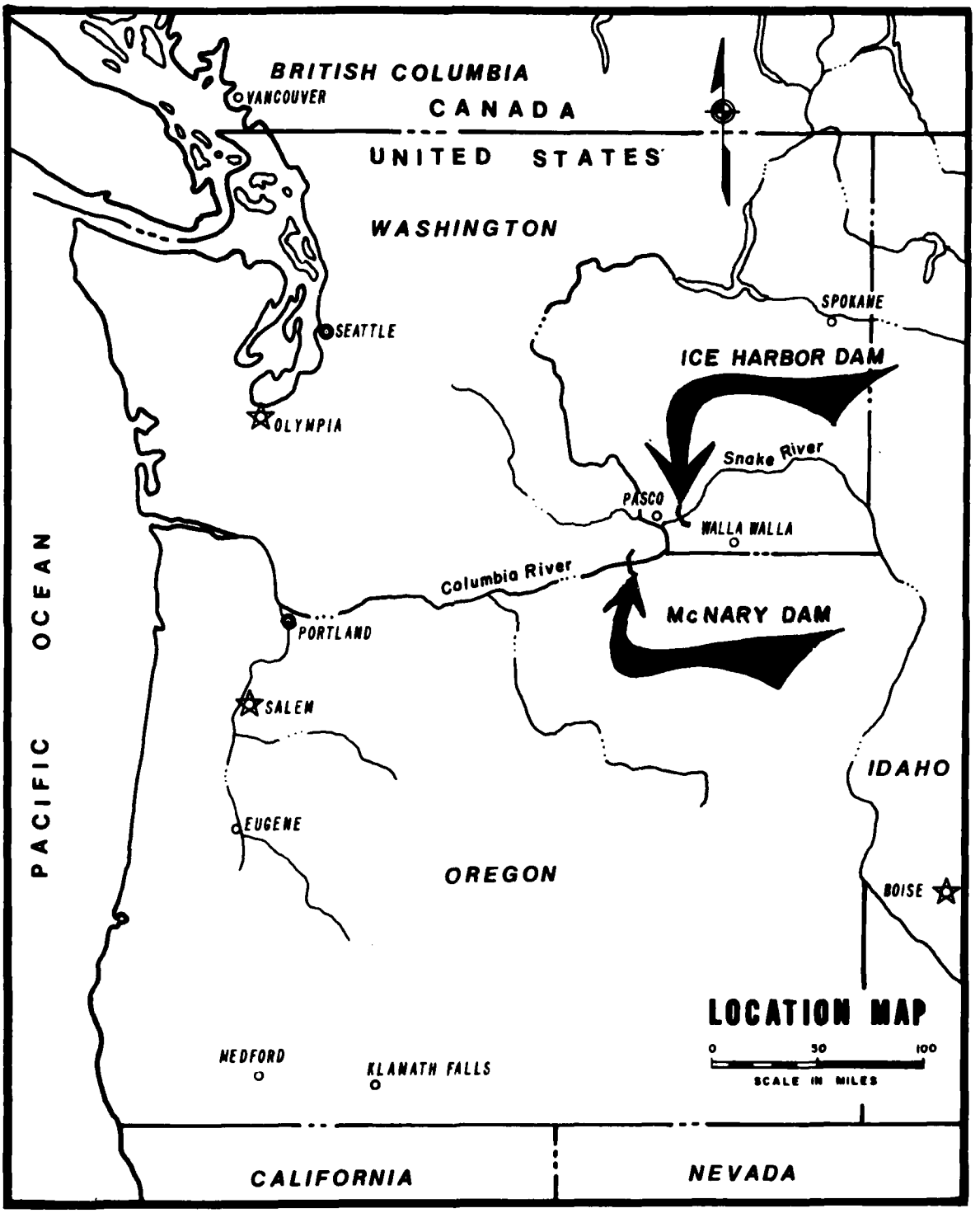
* A table for converting British units of measurement to metric units is presented on page iii.

** All elevations are in feet above mean sea level.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Snake River
PASCO
WALLA WALLA
Columbia River
McNARY DAM
PACIFIC OCEAN
PORTLAND
SALEM
IDAHO
EUGENE
OREGON
BOISE
LOCATION MAP
0 50 100
SCALE IN MILES
MEDFORD
KLAMATH FALLS
CALIFORNIA
NEVADA

Figure 1

at the McNary Dam. Representatives of several towboat companies have stated that leaving the lock was the most difficult maneuver. Discharge from the powerhouse flows across the river and into the navigation channel at an angle with sufficient velocity to require tows to steer an angled course (crab) to stay in the channel. A safety margin of 50 feet on either side of the 250-foot-wide navigation channel is desired with present conditions because towboat operators have no way of knowing exactly where the limits of the channel are between the end of the guide wall and Buoy No. 20, 2,700 feet downstream. Upstream movement into the lock is not as difficult as downstream movement because the relative movement of water past the towboat is faster and provides more-effective steerage.

Purpose of Model Studies

4. A model study was required to determine the feasibility of correcting or improving the navigation problems that result from cross currents from the powerhouse. Some form of guide wall extension or additional channel excavation was proposed as a possible solution to the problem. The effects of the changes on currents around Goose Island, about 8,000 feet downstream of the dam, were also studied because of their potential environmental impact.

PART II: THE MODEL

5. A 1:100-scale model of Ice Harbor Lock and Dam and the downstream navigation channel (figure 2, plate 3, and the photograph 1) was used to study modification to the downstream training wall. The model included the powerhouse, spillway and navigation lock, and approximately 2.3 miles of downstream river and navigation channel. Natural topography and proposed excavation were simulated by heavily grouted sea gravel molded to conform to field surveys and design plans. The dam structures were simulated using waterproofed wood, plywood, and plastic. The study area was exclusively downstream; therefore, only a limited forebay was modeled. Water was introduced into the model through basins located 500 feet upstream of the dam. The water was pumped from large storage tanks to the model through a recirculation system and was measured by calibrated orifices in the supply lines. Discharges through the spillway and powerhouse were calibrated separately to reproduce prototype flow quantities. An overflow tailgate controlled tailwater elevations at gage 9 (plate 3) in accordance with observed and computed water surface elevations. Standard laboratory procedures were used to measure water surface elevations and velocities. Certain flow conditions were recorded photographically.

6. Model measurements were converted to prototype values with equations of similitude based on the Froude model law. The following scale multipliers were used:

Length multipler (L_r)	=	100
Velocity multiplier ($L_r^{1/2}$)	=	10
Discharge multiplier ($L_r^{5/2}$)	=	100,000
Horsepower multiplier ($L_r^{7/2}$)	=	10,000,000

7. The river was modeled from a hydrographic survey made in March 1981, and the river roughness was verified with river water surface data observed during the spring of 1981 (table A). During verification tests, the existing navigation channel was modeled; for all other studies, the planned 1982 channel excavation was modeled.

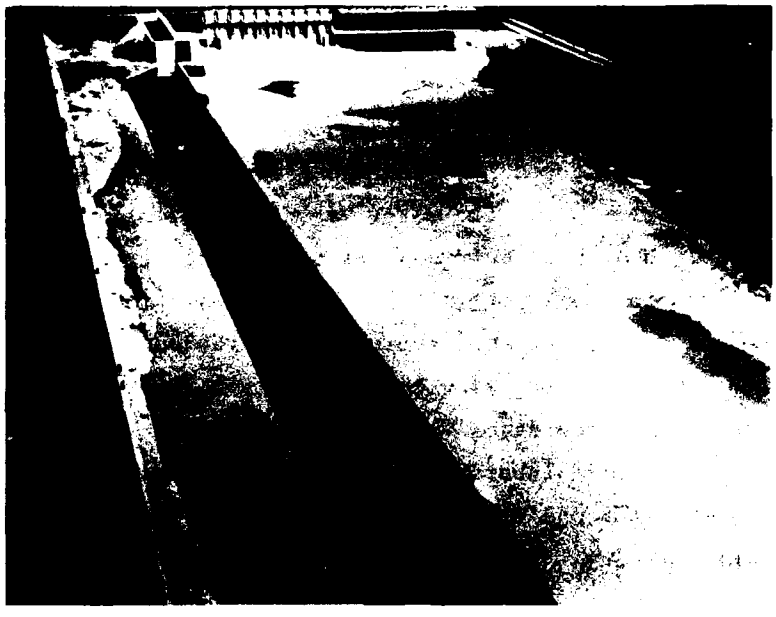


Fig. 2 1:100-scale model of Ice Harbor Lock and Dam and navigation channel

8. A radio-controlled scale model of a 2,000-horsepower towboat was used in conjunction with the barge combinations shown in photograph 2. The barges measured 274 feet long and 42 feet wide with drafts of 13 feet loaded and 4 feet empty. The sizes used were representative of the average size tows. Information obtained from the towboat companies using the lock indicated that a maximum downstream tow would consist of two loaded barges and that a maximum upstream tow would consist of one loaded and two empty barges. Based on model demonstrations with the towboat operators, it was determined that the normal exit of a tow from the lock would be at half speed of the boat along the guide wall, approximate speed of the current at the end of the guide wall, and full speed 600 to 1,000 feet downstream where crossflow from the powerhouse is the strongest. The towboat must be at full speed at the point of crossflow in order to be moving faster than the current and have adequate steerage.

PART III: PERFORMANCE OF EXISTING NAVIGATION CHANNEL

9. The existing navigation channel configuration is comprised of the existing training wall and the planned 1982 channel excavation with the channel dredged to elevation 319 to the downstream end of the model. River discharges of 10,000, 60,000, 100,000, 150,000, 180,000, and 220,000 cfs were observed with tailwater adjusted to simulate controls by McNary Dam pool at elevations 335 and 340 with minimum power flow down the Columbia River from Priest Rapids Dam. Table B shows the effect which the 5-foot difference in McNary pool level has on water levels at Ice Harbor Dam. At higher flows when navigation is difficult, the difference in water level at Ice Harbor was less than 1 foot. There was little or no difference detectable in flow or in navigation conditions due to the difference in McNary pool level, and the results obtained for pool elevation 335 are essentially applicable to both McNary pool levels.

10. The flow pattern immediately downstream of the dam is shown by the confetti streaks in photographs 3, 4, and 5 for river discharges from 10,000 to 220,000 cfs. The flow tended to sweep diagonally across from the powerhouse towards the navigation channel to create a strong crossflow immediately downstream of the training wall. The effect was strongest at 100,000 cfs (photograph 4) with maximum powerhouse flow and zero spillway flow. At higher discharges, the additional spillway flow acted as a buffer to reduce the angle of flow approaching the navigation channel and consequently the degree of crossflow.

11. Photographs 6, 7, and 8 show the flow patterns in the vicinity of Goose Island for the range of flows tested. These pictures were taken to document existing conditions in order to evaluate effects on downstream flow conditions resulting from physical changes in the river channel or structures which were made to improve navigation. The velocities measured around Goose Island are shown in plates 4 to 9.

12. The flow patterns, velocities, and water levels measured in the model are documented in plates 4 to 9 for river discharges of 10,000 to 220,000 cfs. For 10,000 cfs (plate 4) the maximum velocities in the

navigation channel were less then 2 fps. A river discharge of 60,000 cfs passing through the powerhouse (plate 5) created maximum velocities of 8 fps in the navigation channel and 4 fps in the area of maximum crossflow. With 100,000 cfs powerhouse flow and no spill (plate 6), the maximum velocity in the navigation channel was 9 fps and 5 fps in the crossflow. At 150,000 cfs (plate 7) velocities in the channel increased to 10 fps, but the angle of crossflow was reduced due to a buffering effect of spillway flow. At 180,000 cfs (plate 8) velocities reached 11 fps, and at 220,000 cfs (plate 9) velocities reached 12 fps.

13. The movement of modeled barge tows in the existing channel is pictured in photographs 9 and 10 using a multiple-exposure technique to show the position of the tow as it progressed along the channel. There was no difficulty navigating upstream (photograph 9) since the towboat, bucking the flow, had good steerage control all the way. However, a small amount of crabbing against the crossflow was necessary. At 100,000 cfs the towboat required the full 2,000 horsepower to move one full and two empty barges against the current. Moving downstream (photograph 10), the tow had to accelerate while protected by the training wall in order to achieve enough speed over and above the river current to be able to steer against the crossflow. This was not difficult at 10,000 or 60,000 cfs discharges but it required appreciably more crabbing at the latter flow. At a flow of 100,000 cfs, the tow required the full usable width of the channel to crab against the crossflow. Less crabbing was required at 150,000 cfs because of the straightening effect of the spillway flow on the powerhouse flow. At 180,000 cfs -- the upper limit of flow for navigation — the towboat had to travel 1,000 to 1,500 feet before attaining full speed, so steering was not yet optimum while passing the crossflow area. During this difficult maneuver, the tow was pushed far toward the bank and maximum crabbing was required until the tow had the speed needed to hold it within the safety limits of the channel.

PART IV: PERFORMANCE OF GUIDE WALL MODIFICATIONS

Solid Guide Wall Extensions

14. Observations were made of three extensions of the downstream guide wall in line with the navigation channel and three other extensions at 30 degrees to the directon of the channel. The three in-line extensions were 500, 1,000, and 1,500 feet long. The 30-degree extensions were 70, 140, and 210 feet long. These geometries are shown in plates 10 to 15 and photographs 11 and 12 with confetti streaks indicating the flow patterns for a 100,000-cfs river discharge. The measured velocities for the three in-line extensions are shown on plates 10 to 15 for river discharges of both 100,000 (powerhouse flow only) and 150,000 cfs (powerhouse and spillway flow). The flow patterns and velocities are essentially the same for both flows. The crossflow for the 500-foot-long extension was relatively unchanged from the existing conditions, and maximum velocities in the middle of the channel were 8 to 10 fps (plates 10 and 11). The 1,000-foot-long extension isolated the navigation channel for a longer distance but beyond it the flow expanded into the channel with maximum velocities of 10 fps (plates 12 and 13). The 1,500-foot-long extension held the powerhouse flow out of the navigation channel for a greater distance but caused the river channel to become narrower and shallower just downstream from the end of the extension wall. Velocities in the navigation channel increased to 11 fps (plates 14 and 15).

15. The measured velocities for the angled end walls are given in plates 16 to 21 for flows of 100,000 and 220,000 cfs. Velocities were also measured at 150,000 cfs but the differences were too insignificant to justify including in the report. With a 70-foot extension, crossflow was about the same as with no extension. Velocities with the 100,000- and 220,000-cfs flows (plates 16 and 17) were as high as 12 fps, and flow angled across the channel for approximately 1,700 feet downstream from the end of the wall -- essentially the same condition as that without the extension. With a 140-foot extension, an additional 100 feet of the channel at the lock was protected from the crossflow which eventually cut across the channels as strong as it did without an

extension. As shown on plates 18 and 19, maximum velocities in the crossflow were 7 and 10 fps for the two flows - - the same as those without an extension. A 210-foot-long extension forced the crossflow further downstream (plates 20 and 21). The velocities of the crossflow were the same as those occurring with the existing geometry, but the crossflow was spread over a longer reach and the angle was increased. The higher river bottom and narrower channel just downstream from where the crossflow was the strongest forced the surface flow to move across the channel at an angle of approximately 30 degrees (photograph 12).

16. None of the solid guide wall extensions improved navigation. The tows are shown moving downstream in photograph 13. The towboat required full throttle by the time it cleared the end of the guide wall to make a safe exit through the reach. According to towboat captains, normal procedure with present conditions is to leave the lock at low speed, obtain half speed along the existing guide wall, and be up to full speed approximately 1,000 feet downstream from the end of the existing guide wall. Conditions with the 500-foot-long guide wall extension and the associated lower channel velocities required a moderate degree of crab to counteract the angular flow. The 1,000- and 1,500-foot-long wall extensions required much more crabbing because of the increased flow velocity that decreased the steering effectiveness. Conditions with the 1,500-foot-long wall were the most difficult for a safe exit. With the angled wall extension, navigation difficulties were roughly the same as for the existing geometry. Photograph 13 shows the degree of crabbing required to exit the lock with a riverflow of 100,000 cfs. It was desirable to keep the nose of the tow near the riverward side of the channel so that the crossflow could be counteracted. The towboat did not obtain full speed -- the conditions when steering would be most effective -- until the tow was approximately 1,000 feet downstream from the end of the guide wall; by that time, the tow was well into the crossflow and being pushed toward the shore. None of the three wall extensions improved navigation maneuverability. With a riverflow of 150,000 cfs, stronger crabbing was required and still the tow was pushed to the right side of the channel with all three wall extensions. In a

riverflow of 220,000 cfs, the high velocities and crossflow made maneuvering of the tow downstream extremely difficult with any of the three wall extensions.

Open Guide Wall Extension

17. A series of guide wall extensions with gaps were studied on the basis that the separated gaps would diffuse the crossflow that otherwise concentrated at the downstream end of the solid wall. The first geometry tested was a variation of the in-line guide wall extension that had a 300-foot-long gap between the existing wall and a 500-foot-long addition. The next was a series of wall units made of sheet pile cells located downstream from the existing guide wall. Each unit consisted of two 24-foot-diameter cells joined by 8.8-foot-radius connectors with an overall length of 53.5 feet. The purpose of the intermittent wall was to allow a small amount of the crossflow to move into the navigation channel at each gap in the wall but not enough to cause the towboat to oversteer. Groups of three to six units were tested, and the four-unit wall was selected as the most effective in breaking up the crossflow with the fewest cells. The extended wall consisted of a 200-foot space adjacent to the existing guide wall and four units with 150-foot spacing between them for a total extension length of 864 feet.

18. The flow patterns for these geometries are shown in photographs 14 and 15, and the velocities are given in plates 22 to 27. The movements of the downstream tow for these geometries are shown in photograph 16. Velocities were not a problem (plates 22 and 23) with the variation of the guide wall extension that had a 300-foot-long gap, but the strong cross- flow that came through the gap made it very difficult for the towboat to recover before passing the end of the wall into the main crossflow (photograph 16).

19. The sheet pile cells made towboat maneuvering considerably easier. Velocities were 6 fps or less with five or six units (plates 22 to 25). Only one-third power was required with minimum crabbing for safe exodus of the tow with either plan. The four-unit plan was also very easy to maneuver past with maximum velocities of 6 fps (plate 26),

and only a slight degree of crabbing was required to keep in the center of the channel (photograph 16). When the wall was shortened to three units with 150-foot spacing, velocities increased only slightly to 7 fps (plate 27) but slightly more crabbing was required to stay in the center of the channel. The three-unit wall was a workable plan with still only one-third power demand of the towboat, but the four-unit wall was considered optimum.

20. A variation of the three-unit wall was tested having a 200-foot space downstream from the existing guide wall followed by three double units (two 53.5-foot units end to end) with 150-foot spacing between them. This plan produced worse flow conditions in the channel and more crabbing as shown in photographs 15 and 16.

21. Short gravity walls were tested as alternatives to the round-nosed cells. Groups of walls with different spacing were tested at discharges of 100,000 and 150,000 cfs (plates 28 to 34). Encroachment of the crossflow into the navigation channel was worse. The square nose of the wall segments deflected flow further into the navigation channel than the circular cells. The cellular walls were superior.

22. None of the revisions to the guide wall had any effect on flow around Goose Island. Velocities and flow patterns were the same as those with existing conditions.

23. The intermittent wall of sheet pile cells provided the best hydraulic improvement of the problem of crossflow from the powerhouse into the navigation channel. However, during a demonstration for local navigation company representatives objection was raised to the intermittent wall units because they would be in the way of tows going upstream with empty barges. On windy days towboats must push the nose of their tows up to 200 feet riverward from the navigation channel to counteract the force of the wind on the high-riding empty barges. The intermittent wall would not provide sufficient shelter from the wind to alleviate this practice.

PART V: PERFORMANCE OF A WIDER NAVIGATION CHANNEL

24. An alternative to extending the guide wall was to widen the channel. One of the major problems for towboat captains is the inability to determine the lateral position of their tows in the navigation channel. To provide an extra 50-foot safety margin on each side, the channel was widened 100 feet on the river side for 2,700 feet downstream from the guide wall, and downstream navigation was tested with flows of 100,000 and 150,000 cfs. The degree of crabbing was just as severe as in the original channel but the margin of safety was greater (photograph 17). Velocities with riverflows of 10,000, 60,000, 100,000, 150,000, 180,000, and 220,000 cfs are shown on plates 35 to 39. The maximum velocities of 8 and 9 fps were the same as those existing before the channel was widened. Only minimal local change occurred along the new left towline.

25. The general consensus of the navigators present was that widening the channel would not be totally effective. One towboat operator indicated that even if the channel were wider he would not have enough power to get out into the new area (against the crossflow) in order to take advantage of it. Others indicated that they could get out into the area but the extra dredging would not be worth the investment. They all agreed that channel widening would not worsen conditions.

26. Several other schemes of offset walls, angled intermittent walls, and combinations of walls and excavation were suggested and tried during the joint work session and at a later demonstration of the model. Those present agreed that none of the schemes adequately improved navigation conditions. No other suggestions for improved navigation were made and testing was terminated.

PART VI: SUMMARY

27. None of the modifications formally tested, including guide wall extensions and channel widening, succeeded (to the satisfaction of the tow operators) in correcting the difficulties experienced while navigating barge tows downstream from the Ice Harbor Lock due to conditions caused by crossflows from the powerhouse. All other modifications explored superficially during workshop sessions with tow operators were also unsuccessful or impractical.

28. The solid 500-, 1,000-, and 1,500-foot-long extensions to the existing 600-foot-long guide wall all caused concentrated crossflows at the end of the guidewall, and the longer extensions restricted the powerhouse flows so that the velocities were higher downstream. Navigation was more difficult because the tows had to achieve a speed in excess of these velocities in order to have rudder control.

29. The short-angled extensions of 70-, 140-, and 210-foot-long had essentially no effect on the crossflow and consequently provided no improvement to downstream navigation.

30. Open extensions that allowed the powerhouse flow to enter the navigation channel through gaps were successful in reducing the concentration of crossflows and allowed the barge tows to move downstream without employing excessive crabbing to stay in the channel. The most effective configuration had four units consisting of pairs of 24-foot-diameter sheet pile cells spaced 150 feet apart with a 200-foot space adjacent to the existing guide wall -- for a total length of 864 feet. However, open extensions were not satisfactory to the tow operators because upstream tows have to travel as much as 200 feet south of the navigation channel to avoid being blown by high winds onto the north bank and the cellular units would be in the way.

31. Widening the navigation channel from 250 feet to 350 feet by dredging a 100- foot-path on the south side did not change the crossflow or reduce the amount of crabbing required to navigate downstream but did provide more safety clearance. However, the consensus of the operators was that this would not help a great deal and some would have difficulty moving their tow southward against the crossflow to take advantage of the increased width.

TABLE A

ELEVATION-DISCHARGE RATING TABLE

SNAKE RIVER NAVIGATION CHANNEL BELOW ICE HARBOR DAM

1981 OBSERVED DATA

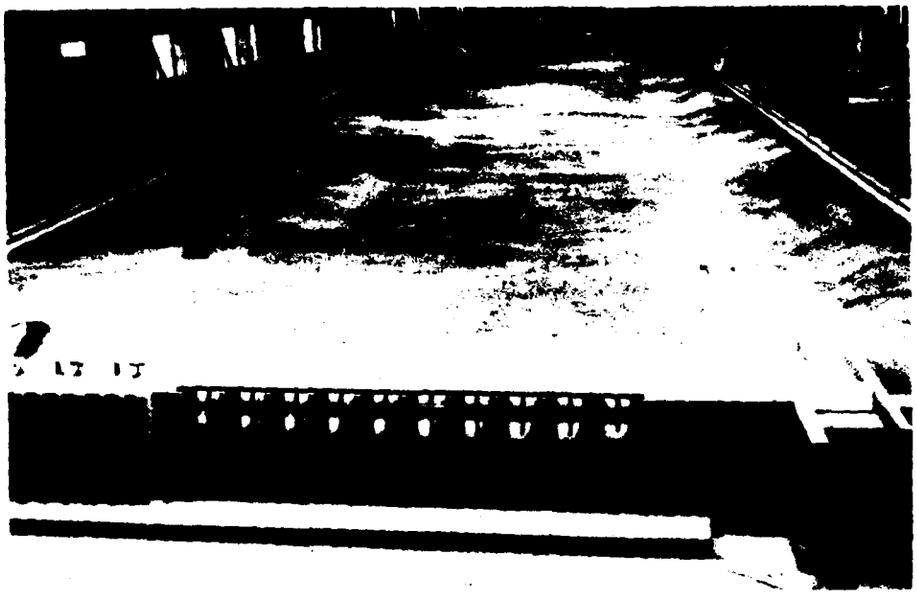
Discharge in cfs		McNary Forebay Elevations in Feet					
		335	337	340	335	337	340
		Water Surface Elevations in Feet					
Snake R.	Columbia R.	Gage 9 at Pumping Plant			Gage 3 at Navigation Lock		
0	36,000	335.0	337.0	340.0	335.0	337.0	340.0
10,000	46,000	335.3	337.2	340.1	335.9	337.5	340.2
50,000	86,000	338.6	339.4	341.3	341.8	342.2	343.1
100,000	136,000	342.3	342.7	343.7	346.6	346.7	347.1
150,000	186,000	345.3	345.6	346.2	350.1	350.2	350.4
200,000	236,000	347.9	348.1	348.6	353.0	353.1	353.3
250,000	286,000	350.2	350.4	350.8	355.6	355.6	355.8
300,000	336,000	352.4	352.5	352.7	357.9	358.0	358.1
350,000	386,000	354.3	354.4	354.5	360.0	360.1	360.2

Note: Gage locations shown on plate 3.

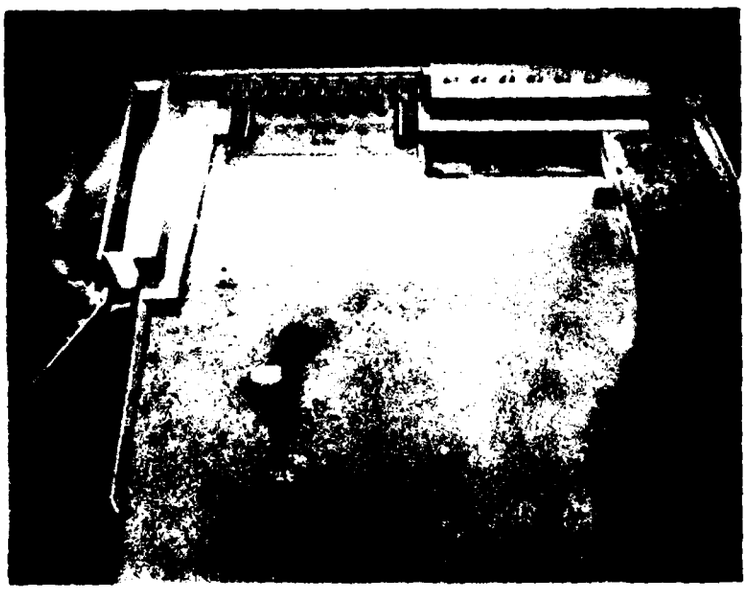
TABLE B

WATER LEVELS RECORDED ON THE MODEL

River Discharge in cfs	Water Levels in Feet at Gage 9 at Downstream End of Model		Water Levels in Feet at Gage 3 at Naviation Lock	
	McNary Pool Levels in Feet			
	335	340	335	340
10,000	335.6	340.1	336.0	340.3
60,000	339.4	341.7	342.7	344.0
100,000	342.3	343.7	346.2	346.9
150,000	345.3	346.2	349.5	350.0
180,000	346.9	347.7	351.2	351.5
220,000	348.9	349.5	353.5	353.5

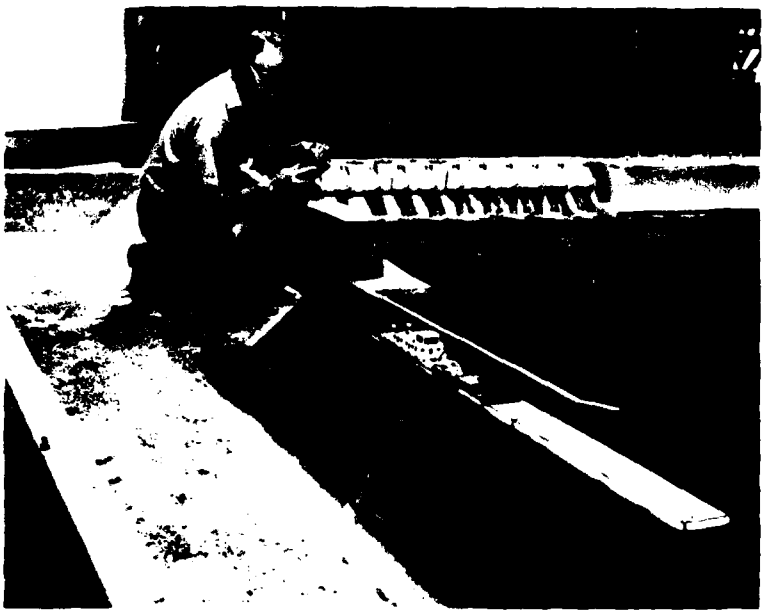


Model before verification changes, viewed from upstream.



Model after verification changes, viewed from above and looking upstream.

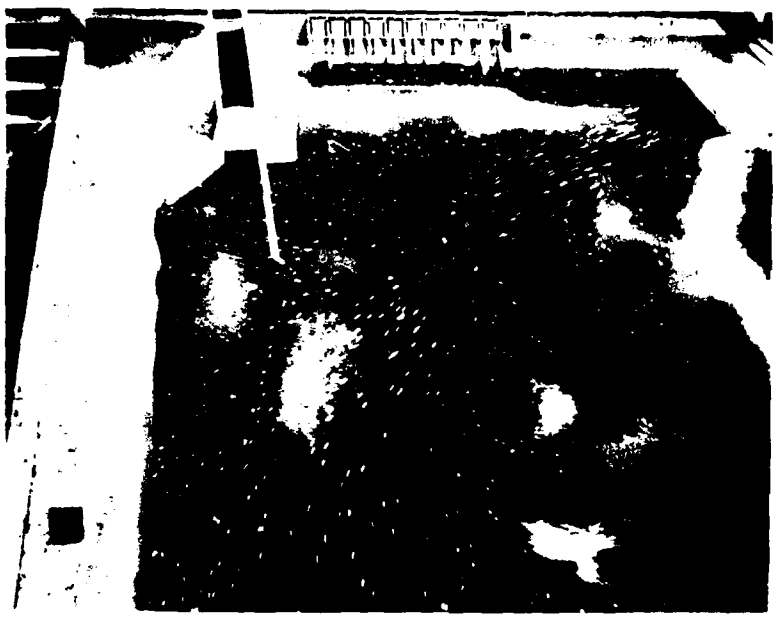
Photograph 1. Model of Ice Harbor Lock and Dam and navigation channel.



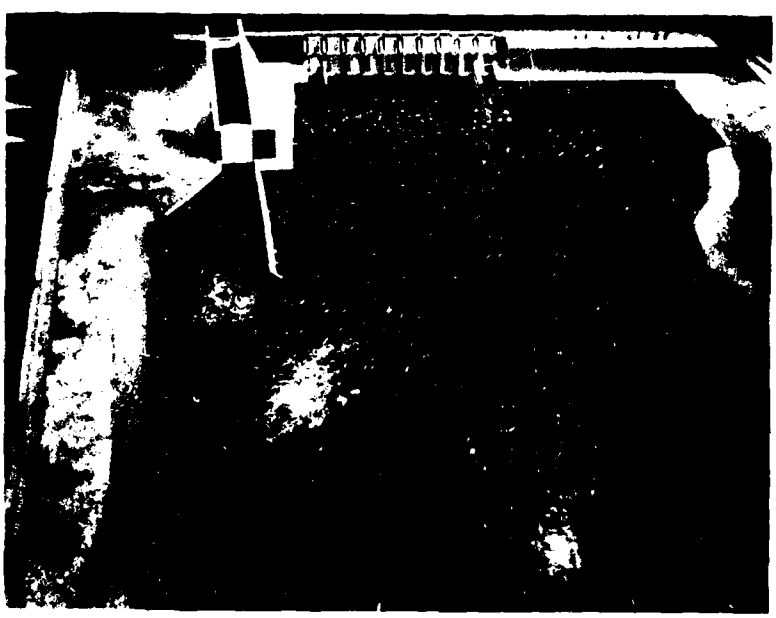
Towboat with two loaded barges for downstream navigation.

Towboat with one loaded barge and two unloaded barges for upstream navigation.

Photograph 2. Radio controlled model towboat with barges.

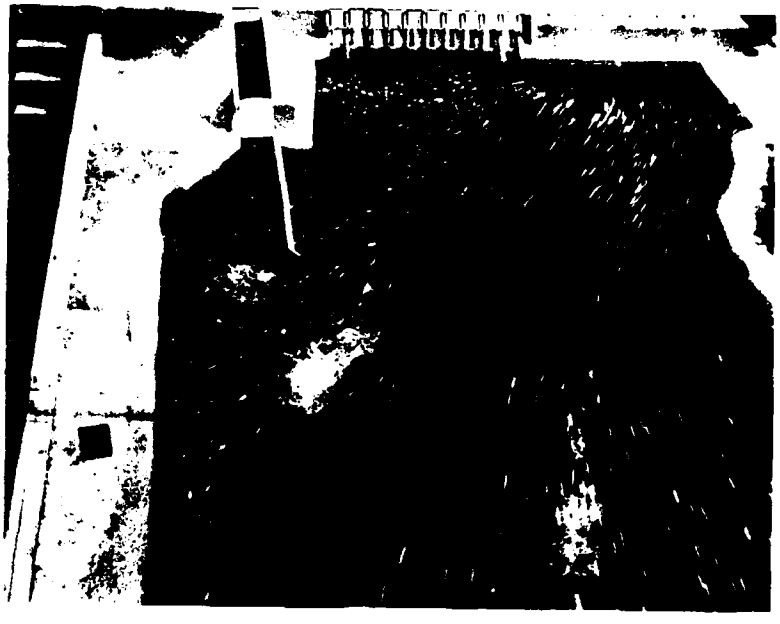


River discharge of 10,000 cfs from Unit 1.



River discharge of 60,000 cfs from Units 1 to 4.

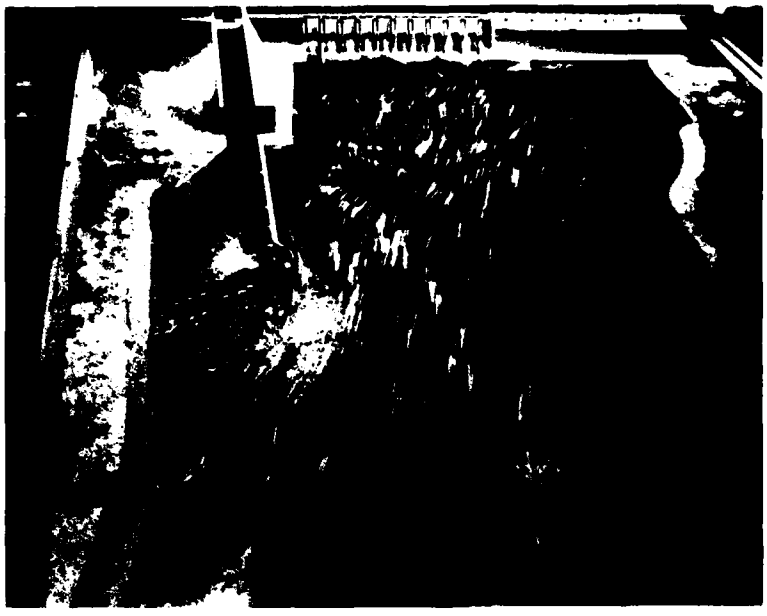
Photograph 3. Water surface flow conditions with existing channel and McNary pool at elev 335. River discharges of 10,000 & 60,000 cfs



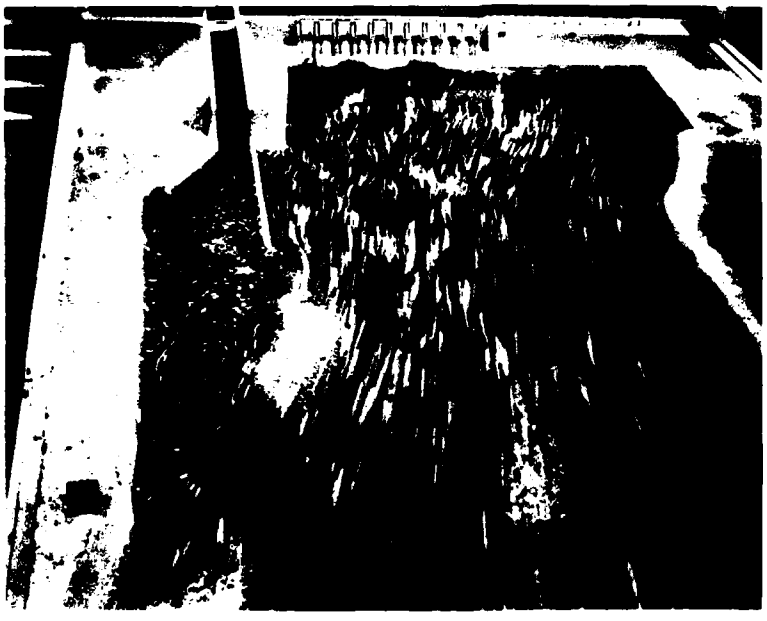
River discharge of 100,000 cfs from Units 1 to 6.

River discharge of 150,000 cfs; 100,000 cfs from powerhouse and 50,000 cfs from spillway.

Photograph 4. Water surface flow conditions with existing channel and McNary pool at elev 335. River discharges of 100,000 and 150,000 cfs

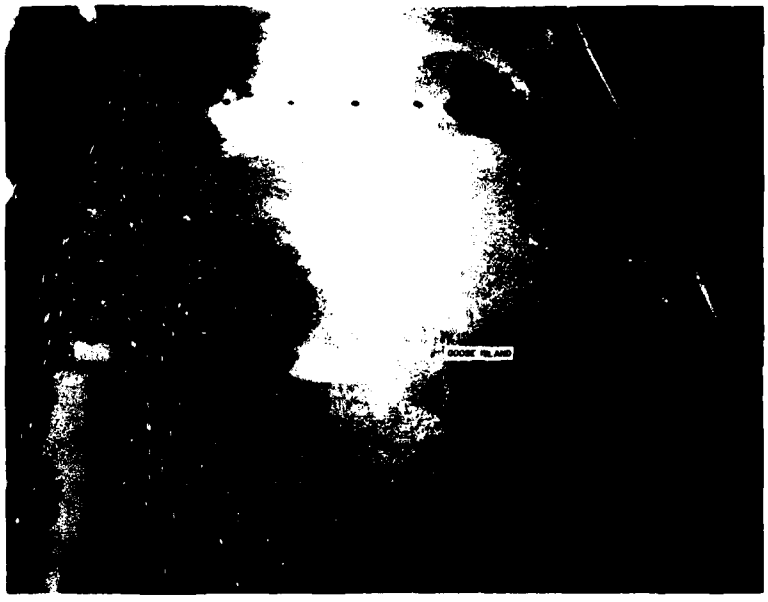


River discharge of 180,000 cfs; 100,000 cfs from powerhouse and 80,000 cfs from spillway.



River discharge of 220,000 cfs; 100,000 cfs from powerhouse and 120,000 from spillway.

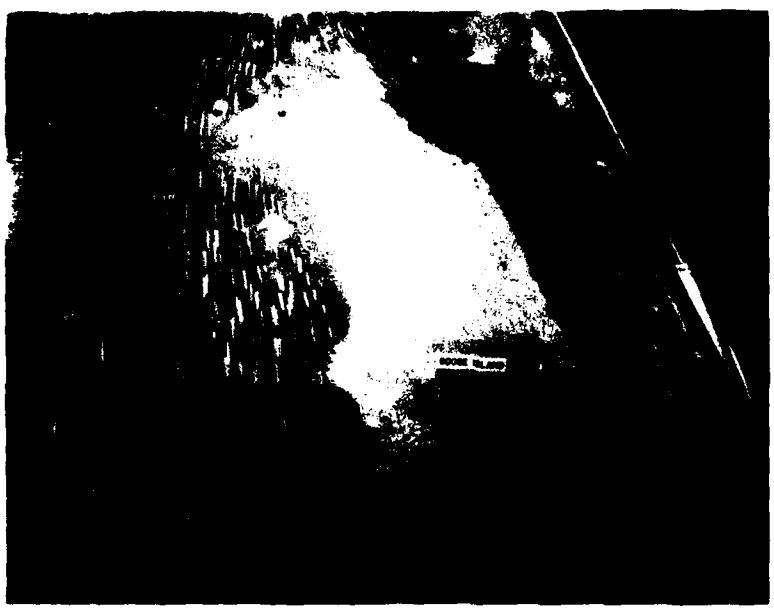
Photograph 5. Water surface flow conditions with existing channel and McNary pool at elev 335. River discharges of 180,000 and 220,000 cfs



10,000 cfs, water surface elev 336

60,000 cfs, water surface elev 341

Photograph 6. Surface flow pattern around Goose Island, McNary pool elev 335, river discharges 10,000 and 60,000 cfs



100,000 cfs, water surface at elev 344

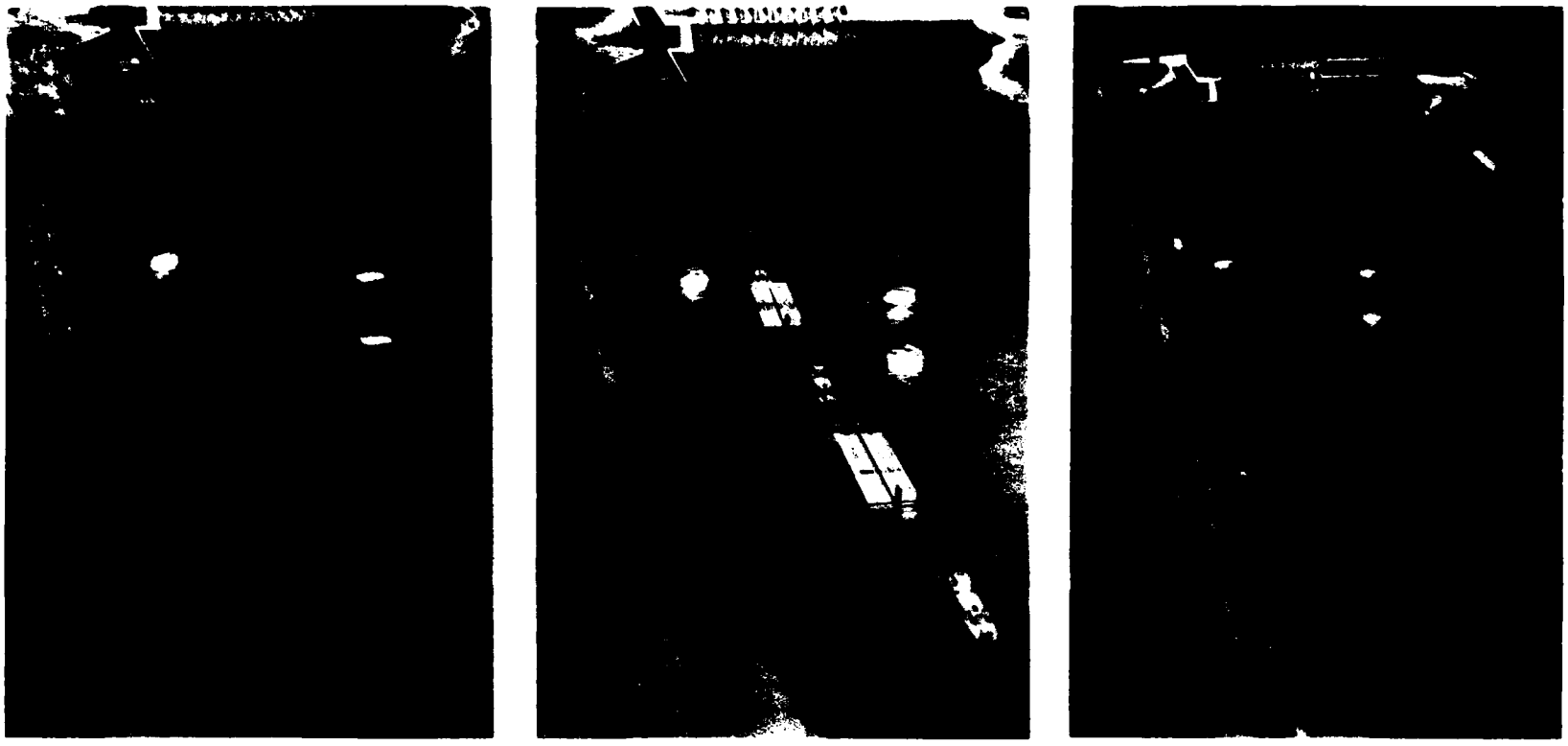
150,000 cfs, water surface at elev 347

Photograph 7. Surface flow pattern around Goose Island, McNary pool at elev 335, river discharge of 100,000 & 150,000 cfs

180,000 cfs, water surface at elev 349

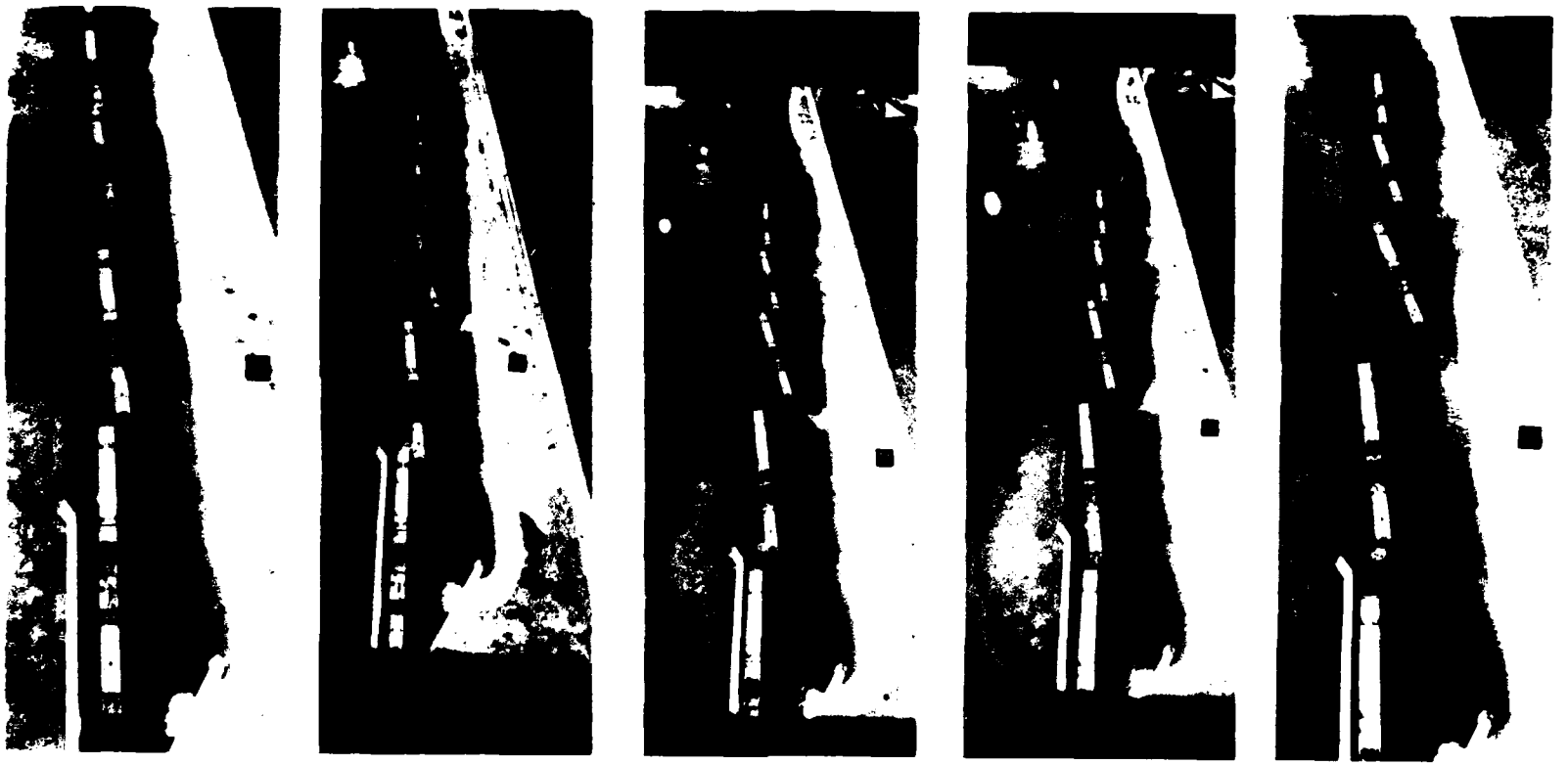
220,000 cfs, water surface at elev 351

Photograph 8. Surface flow pattern around Goose Island, McNary pool at elev 335, river discharges of 180,000 & 220,000 cfs



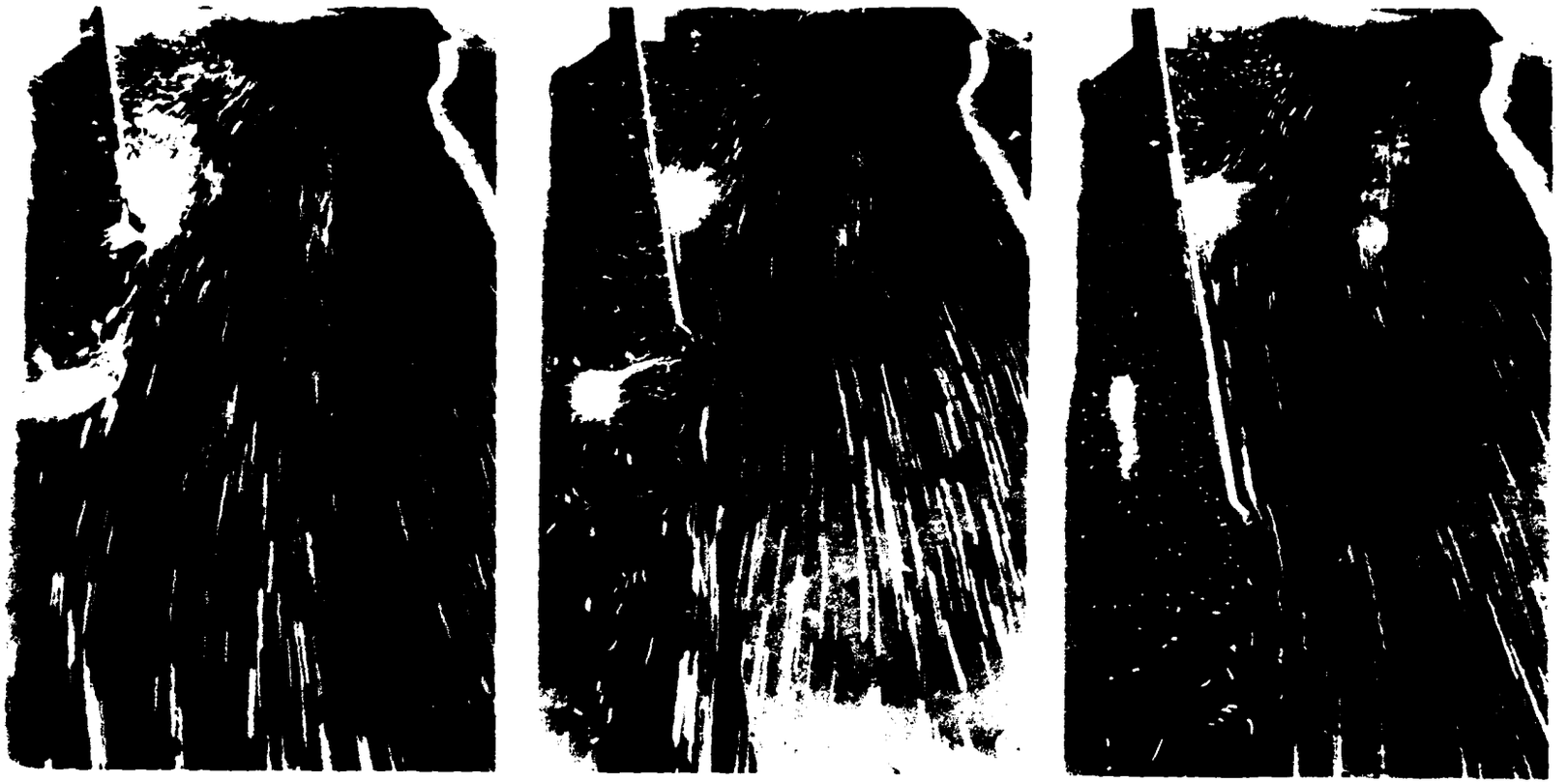
River discharge of 10,000 cfs | River discharge of 60,000 cfs | River discharge of 100,000 cfs

Photograph 9. Multiple exposures of tow navigating upstream in existing channel, and McNary pool at elev 335



10,000 cfs 60,000 cfs 100,000 cfs 150,000 cfs 180,000 cfs

Photograph 10. Multiple exposures of tow navigating downstream in existing channel, McNary pool at elev 335

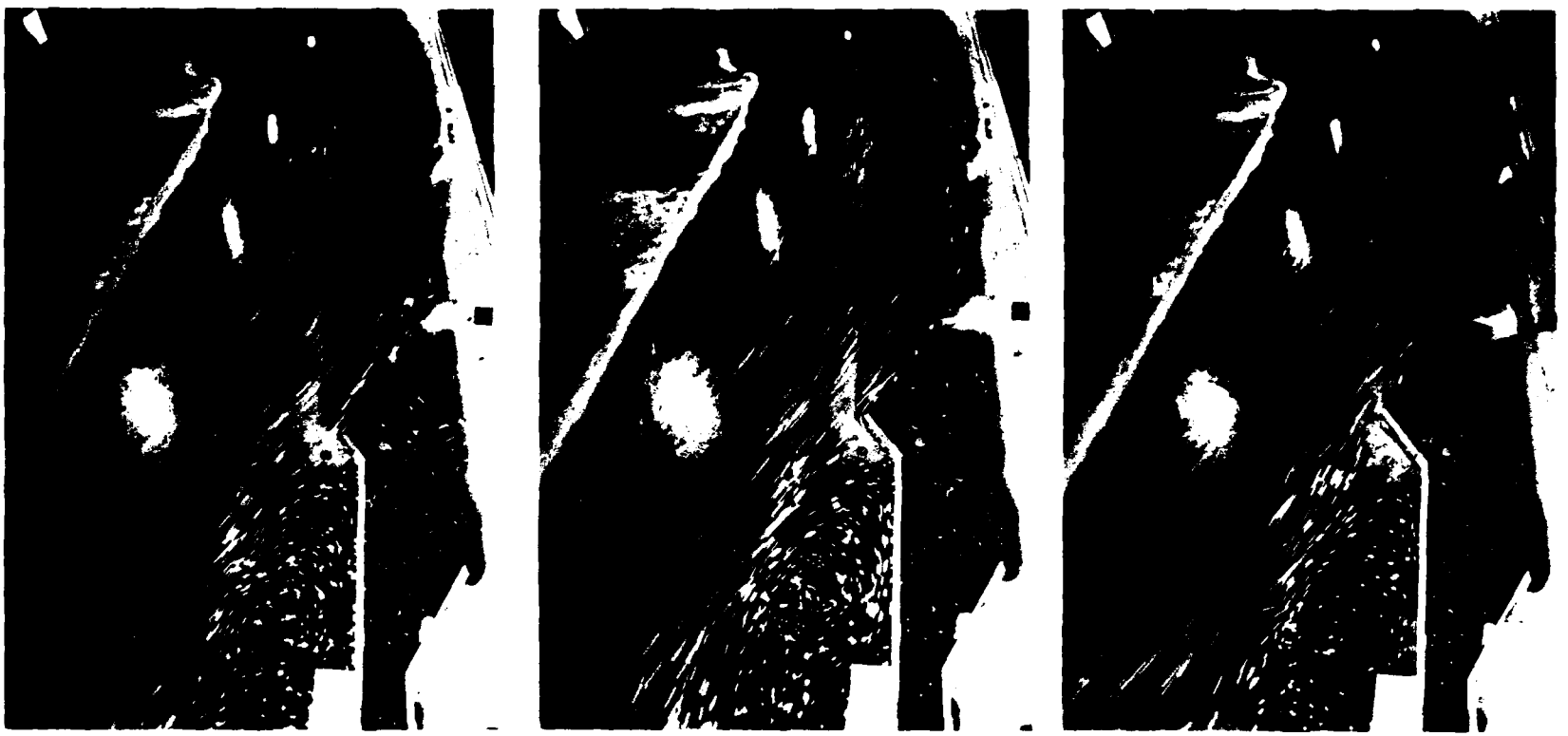


500-ft wall extension

1000-ft wall extension

1500-ft wall extension

Photograph 11. Water surface flow conditions with solid guidewall extensions, river discharge at 100,000 cfs and McNary pool at elev 335



70-ft wall extension at 30 degrees

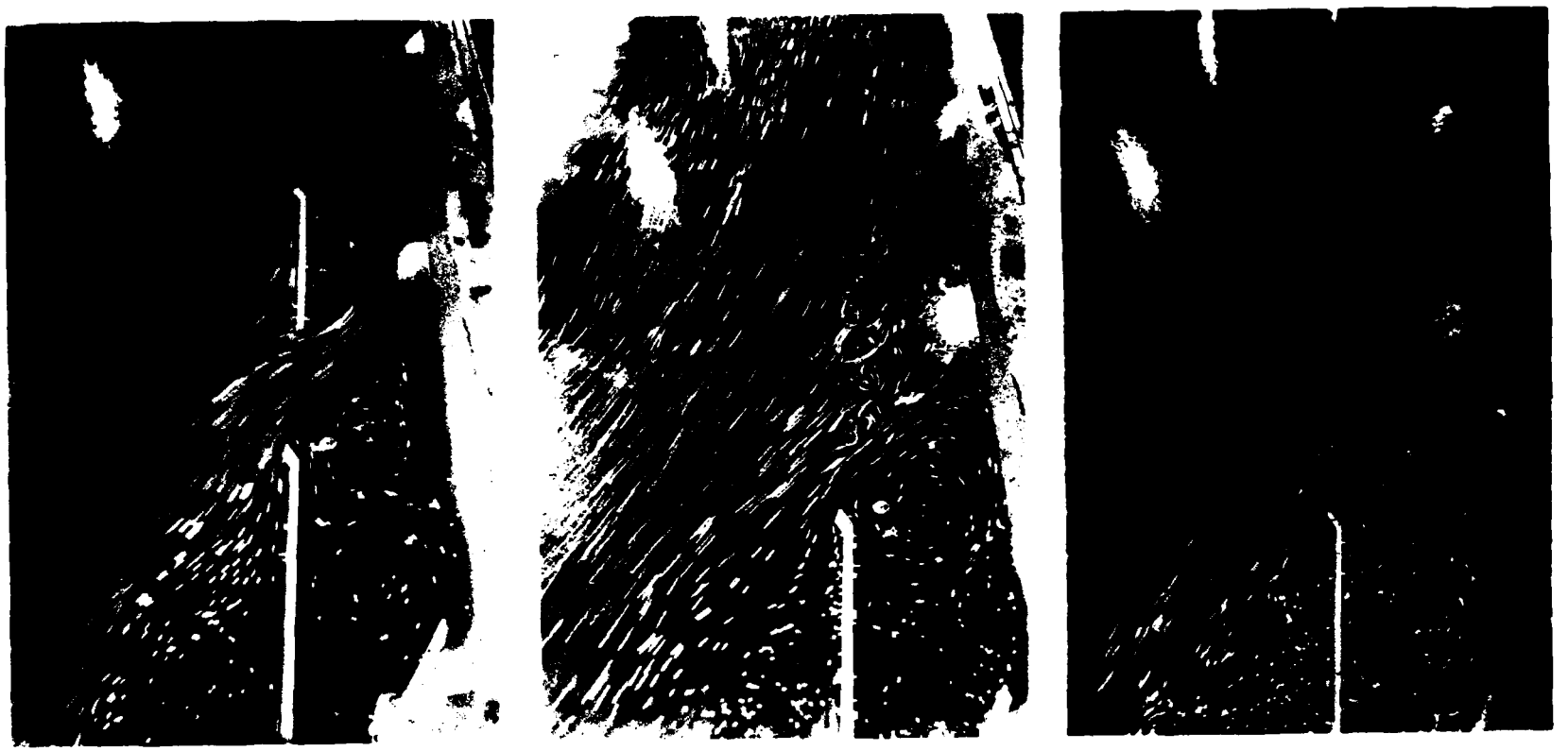
140-ft wall extension at 30 degrees

210-ft wall extension at 30 degrees

Photograph 12. Water surface flow conditions with angled guidewall extensions, river discharge at 100,000 cfs and McNary pool at elev 335

500-ft ext. 1000-ft ext. 1500-ft ext. 70-ft 30° ext. 140-ft 30° ext. 210-ft 30°ext.

Photograph 13. Multiple exposures of tow navigating downstream with solid guide wall extensions, river discharge 100,000 cfs and McNary pool at elev 335

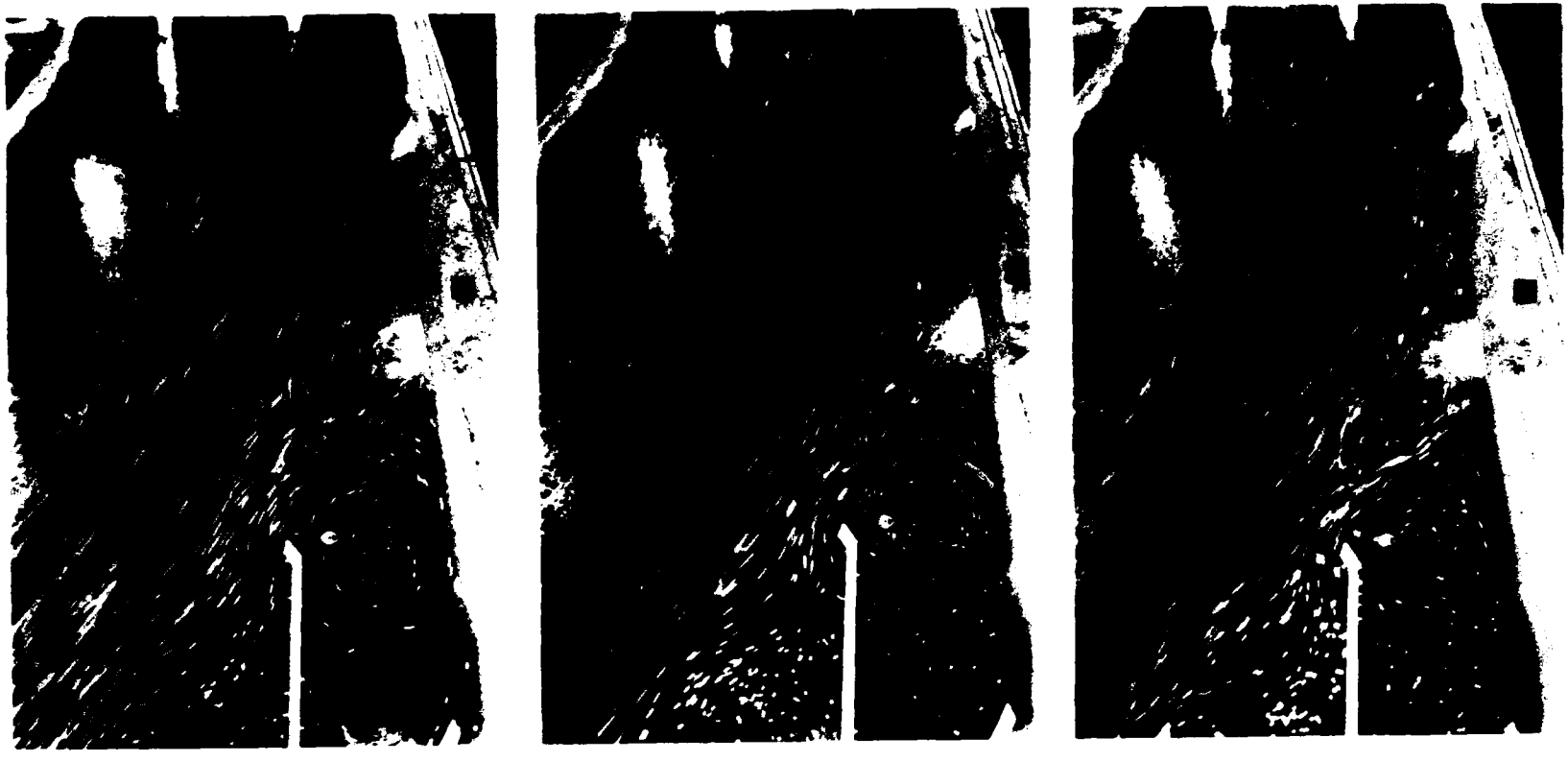


500-ft extension with 300-ft gap

six-unit extension at 70-ft spacing

five-unit extension at 100-ft spacing

Photograph 14. Water surface flow conditions with open guidewall extensions, river discharge of 100,000 cfs and McNary pool at elev 335

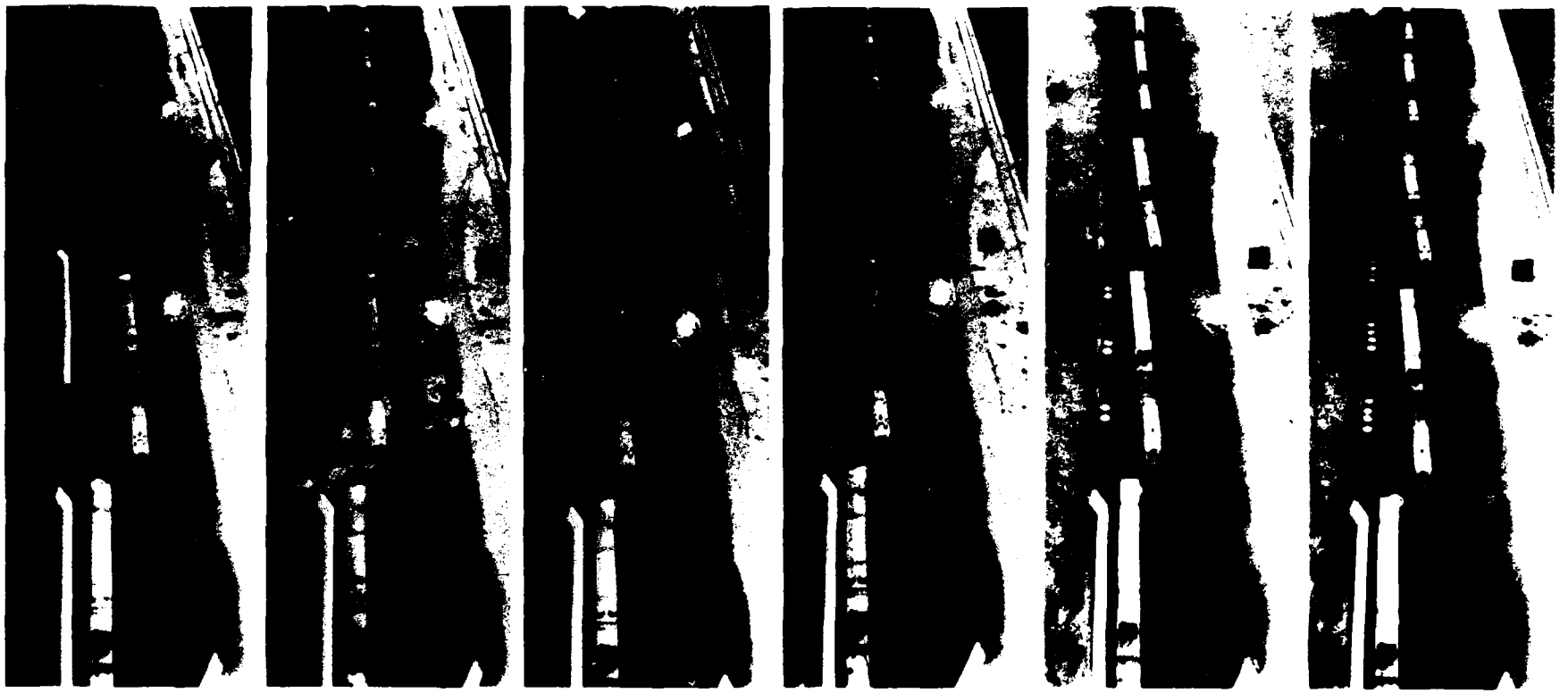


four-unit extension at 150-ft spacing

three-unit extension at 150-ft spacing

three double-unit extension at 150-ft spacing

Photograph 15. Water surface flow conditions with open guidewall extensions, river discharge 100,000 cfs and McNary pool elev 335



500-ft ext.
300-ft gap

six-unit ext.
70-ft spacing

five-unit ext.
100-ft spacing

four-unit ext.
150-ft spacing

three-unit ext.
150-ft spacing

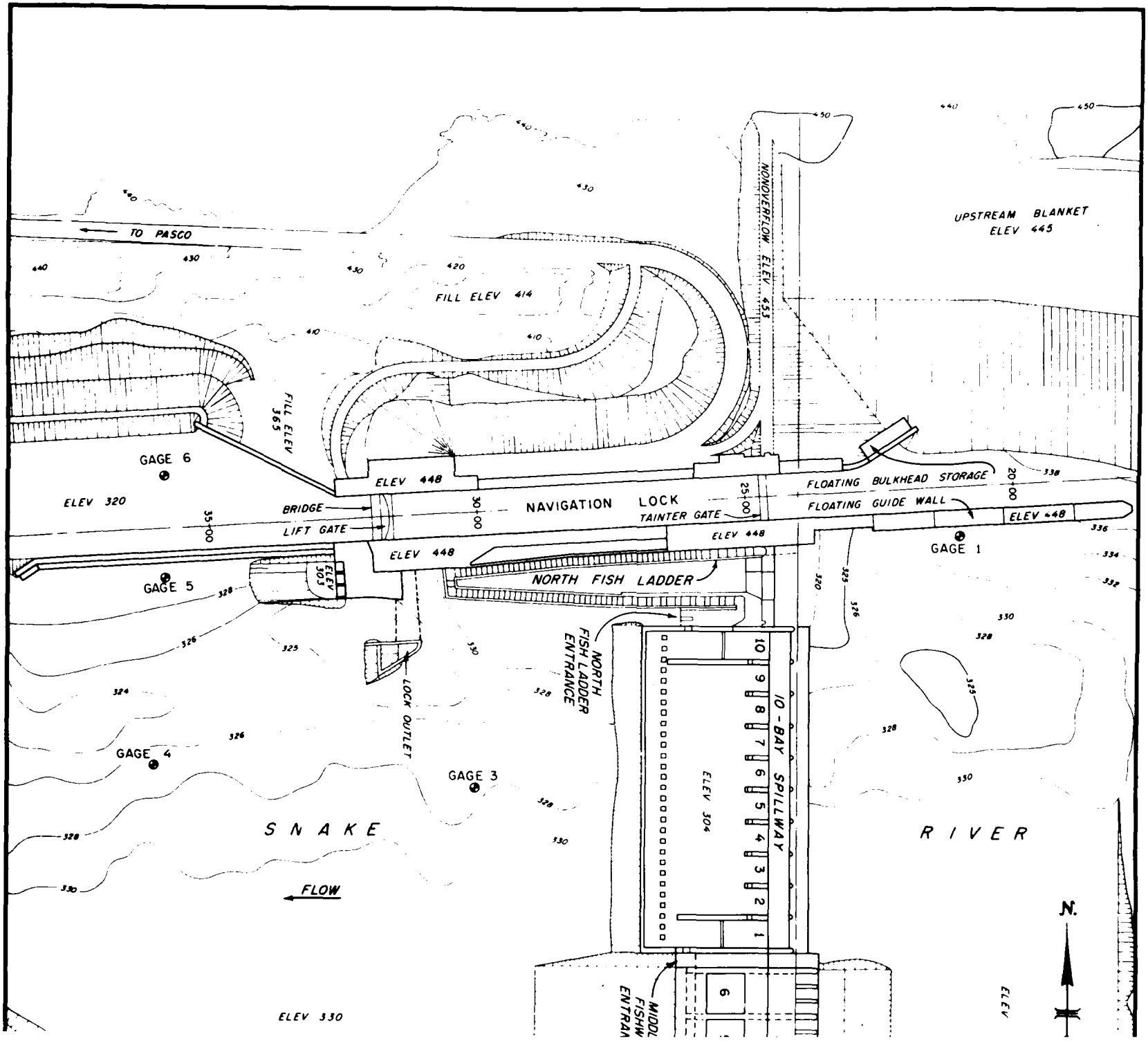
three-unit
double ext.
150-ft spacing

Photograph 16. Multiple exposures of tow navigating downstream with open guide wall extensions, river discharge of 100,000 cfs and McNary pool at elev 335

River discharge of 100,000 cfs

River discharge of 150,000 cfs

Photograph 17. Multiple exposures of tow navigating downstream with no wall extension but channel widened to 350 ft. McNary pool at elev 335


TO PASCO
FILL ELEV 414
FILL ELEV 365
NONOVERFLOW ELEV 453
UPSTREAM BLANKET ELEV 445
GAGE 6
ELEV 320
ELEV 448
BRIDGE
LIFT GATE
NAVIGATION LOCK
TAINTER GATE
FLOATING BULKHEAD STORAGE
FLOATING GUIDE WALL
ELEV 448
GAGE 1
GAGE 5
ELEV 305
NORTH FISH LADDER
NORTH FISH LADDER ENTRANCE
LOCK OUTLET
10-BAY SPILLWAY
ELEV 304
GAGE 4
GAGE 3
SNAKE
RIVER
FLOW
ELEV 330
N.

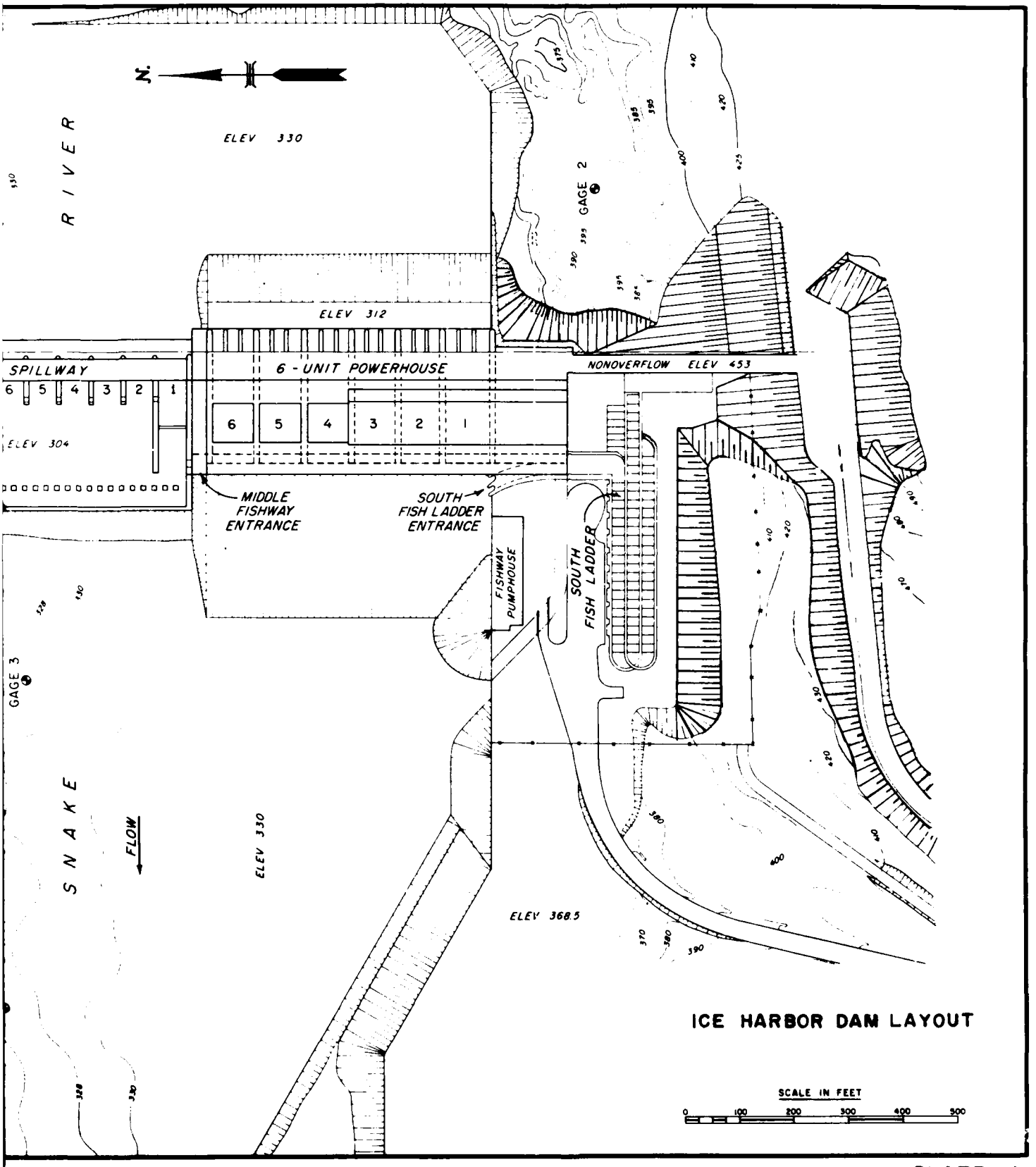
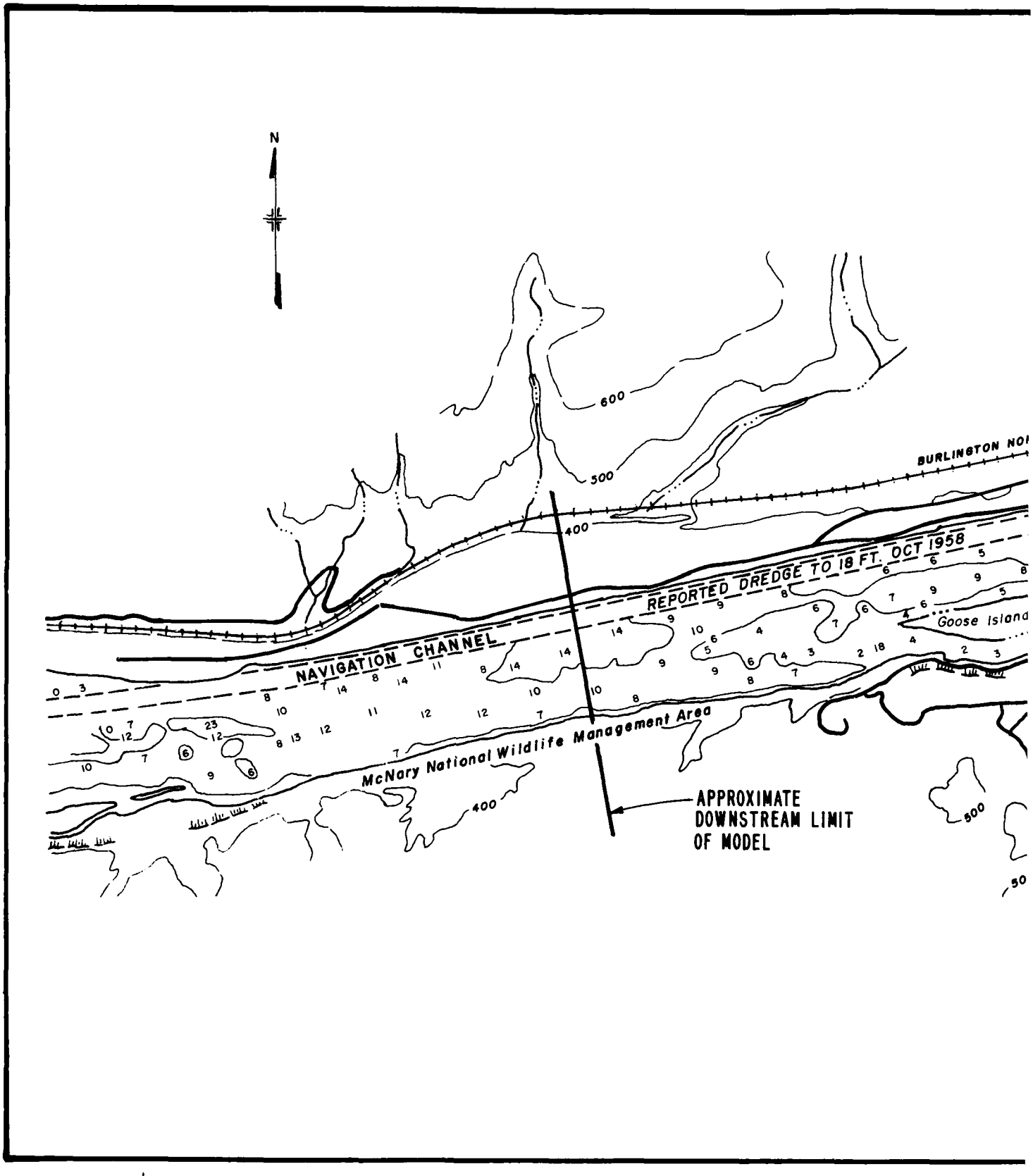

N.
RIVER
ELEV 330
GAGE 2
ELEV 312
SPILLWAY
6 5 4 3 2 1
6 - UNIT POWERHOUSE
NONOVERFLOW ELEV 453
6 5 4 3 2 1
ELEV 304
MIDDLE FISHWAY ENTRANCE
SOUTH FISH LADDER ENTRANCE
FISHWAY PUMPHOUSE
SOUTH FISH LADDER
GAGE 3
SNAKE
FLOW
ELEV 330
ELEV 368.5
ICE HARBOR DAM LAYOUT
SCALE IN FEET
0 100 200 300 400 500

PLATE 1


N
600
500
400
BURLINGTON NO
REPORTED DREDGE TO 18 FT. OCT 1958
NAVIGATION CHANNEL
Goose Island
McNary National Wildlife Management Area
APPROXIMATE
DOWNSTREAM LIMIT
OF MODEL
400
500

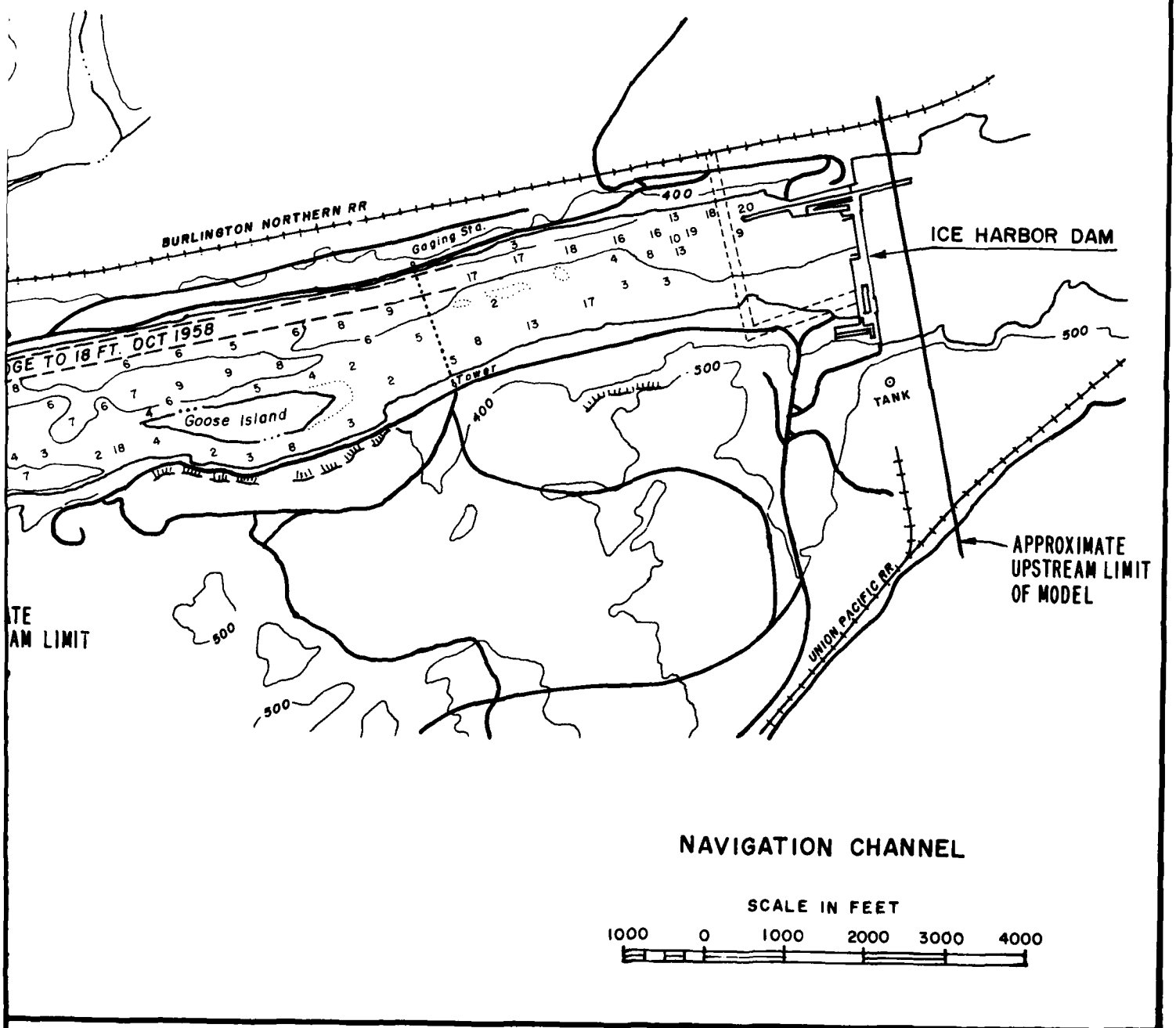
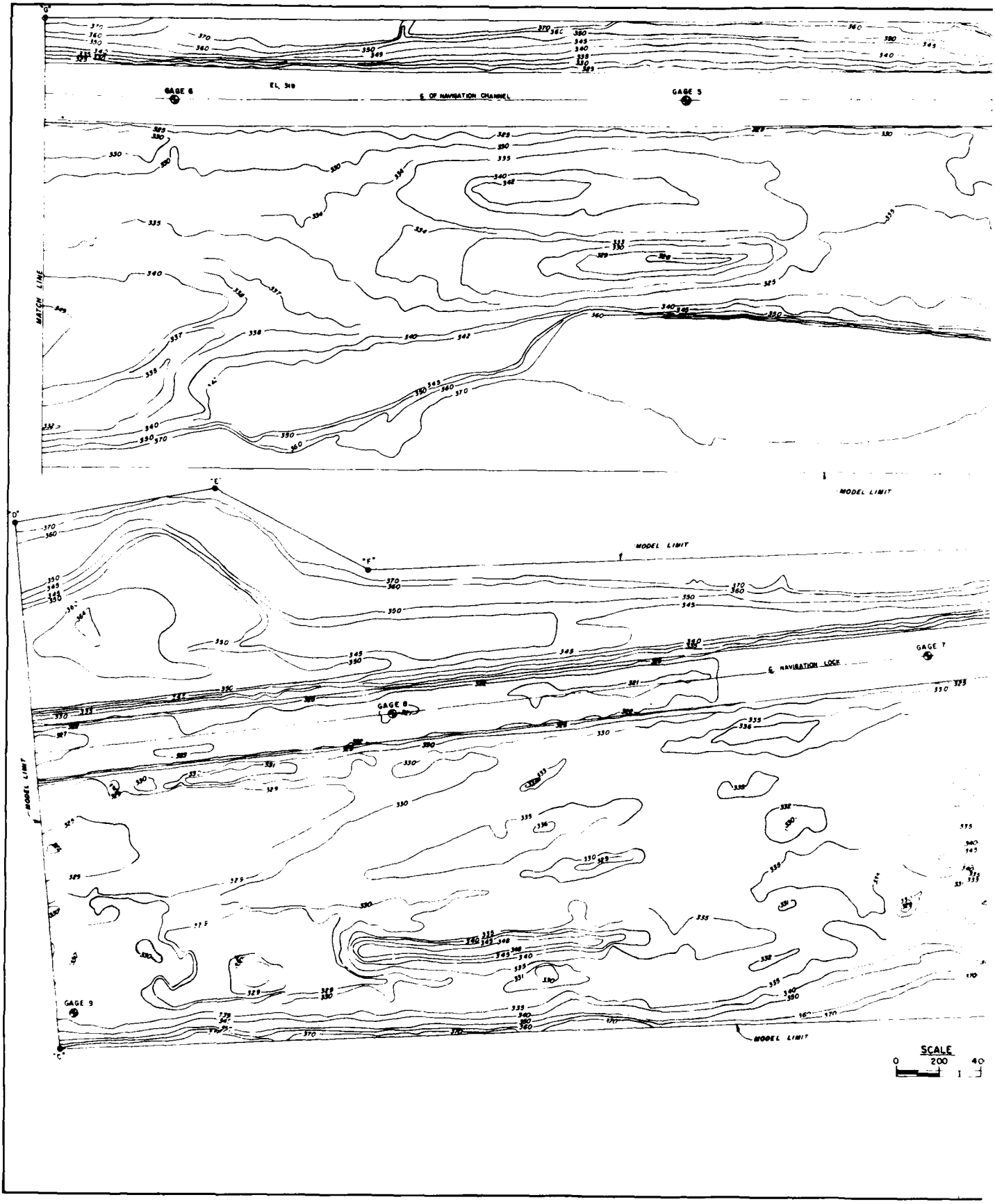
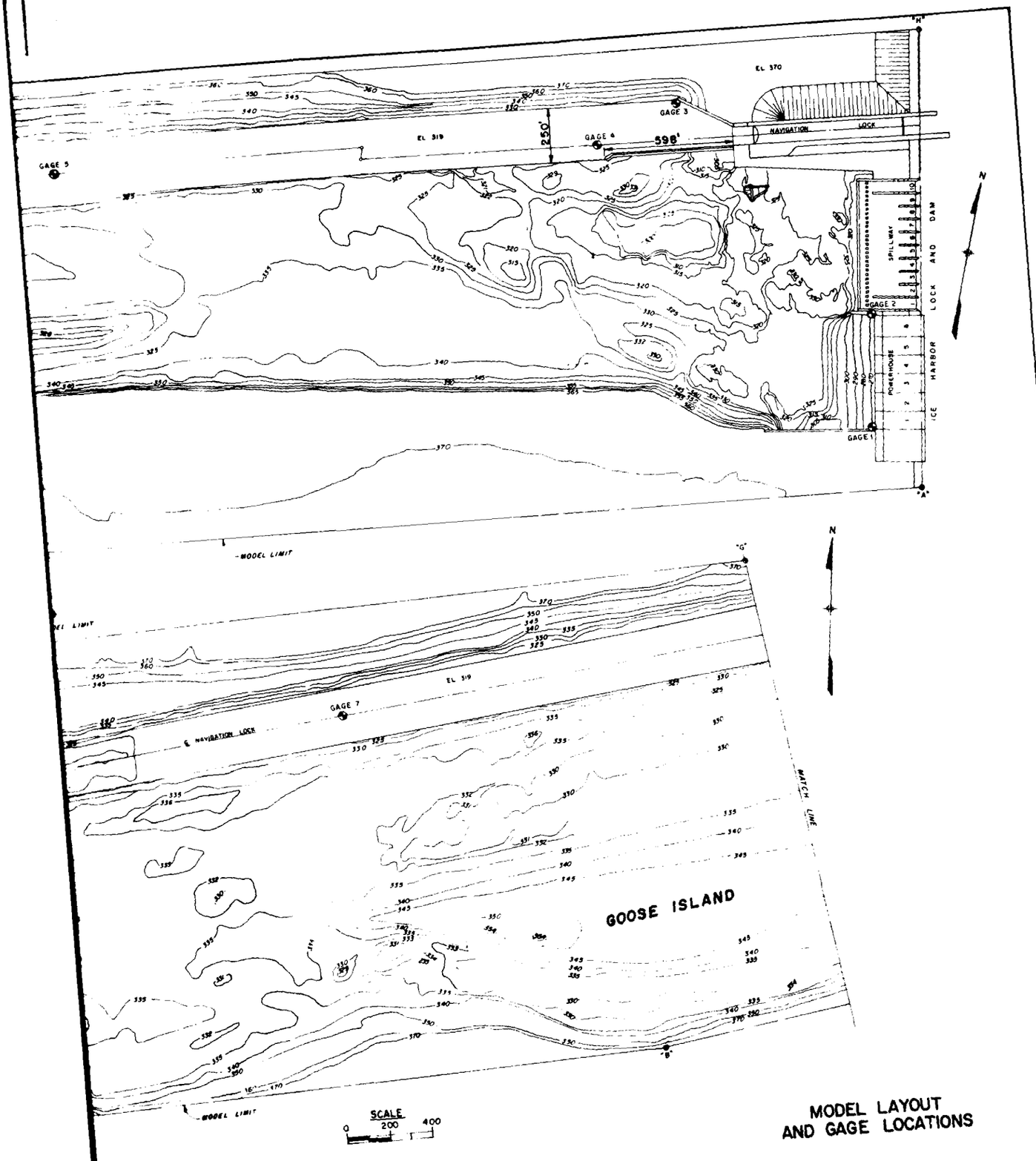

BURLINGTON NORTHERN RR
Gaging Sta.
ICE HARBOR DAM
GE TO 18 FT. OCT 1958
Tower
Goose Island
TANK
APPROXIMATE
UPSTREAM LIMIT
OF MODEL
TE
AM LIMIT
UNION PACIFIC RR.
400
500
NAVIGATION CHANNEL
SCALE IN FEET
1000 0 1000 2000 3000 4000

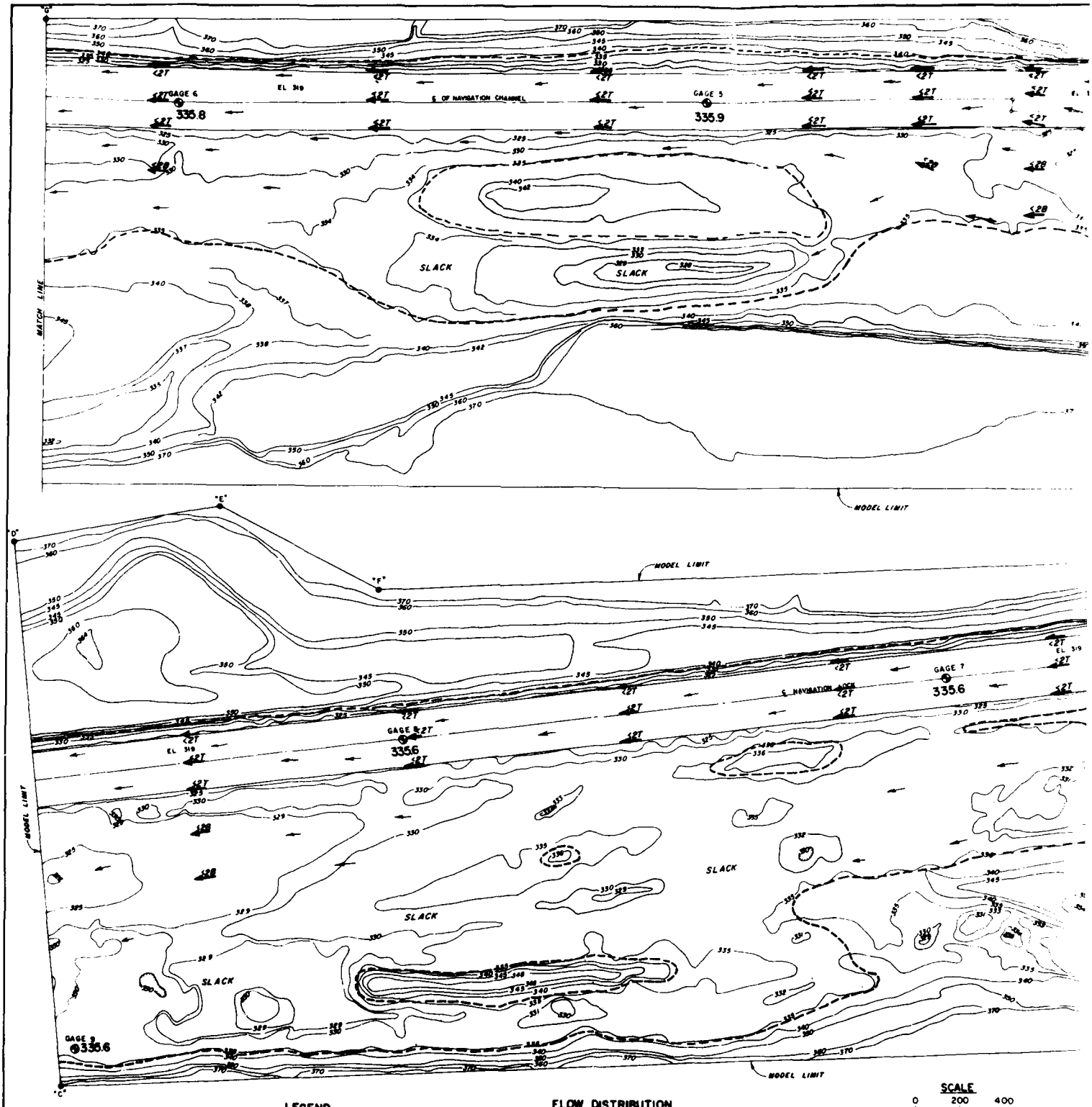
PLATE 2


GAGE 6
EL. 340
℄ OF NAVIGATION CHANNEL
GAGE 5
MATCH LINE
MODEL LIMIT
"E"
"D"
"C"
GAGE 7
℄ NAVIGATION LOCK
GAGE 8
GAGE 9
SCALE
0
200
400



MODEL LAYOUT
AND GAGE LOCATIONS

PLATE 3



LEGEND

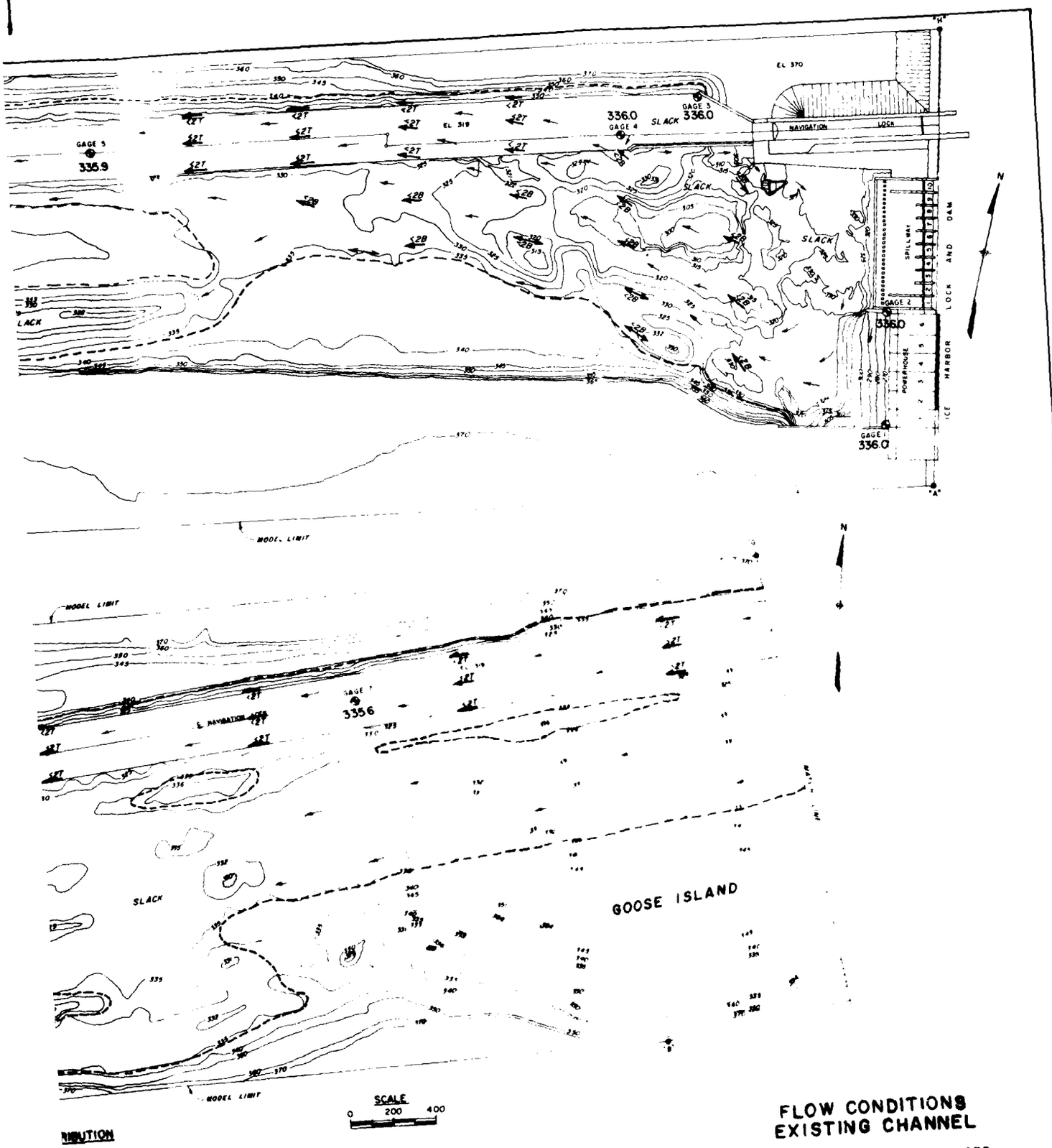
- VELOCITIES MEASURED IN FPS
- T 7-FT DEPTH
- B 5 FT OFF BOTTOM
- FLOW DIRECTION

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNIT 1	10 000 CFS

SCALE

0 200 400



RIBUTION

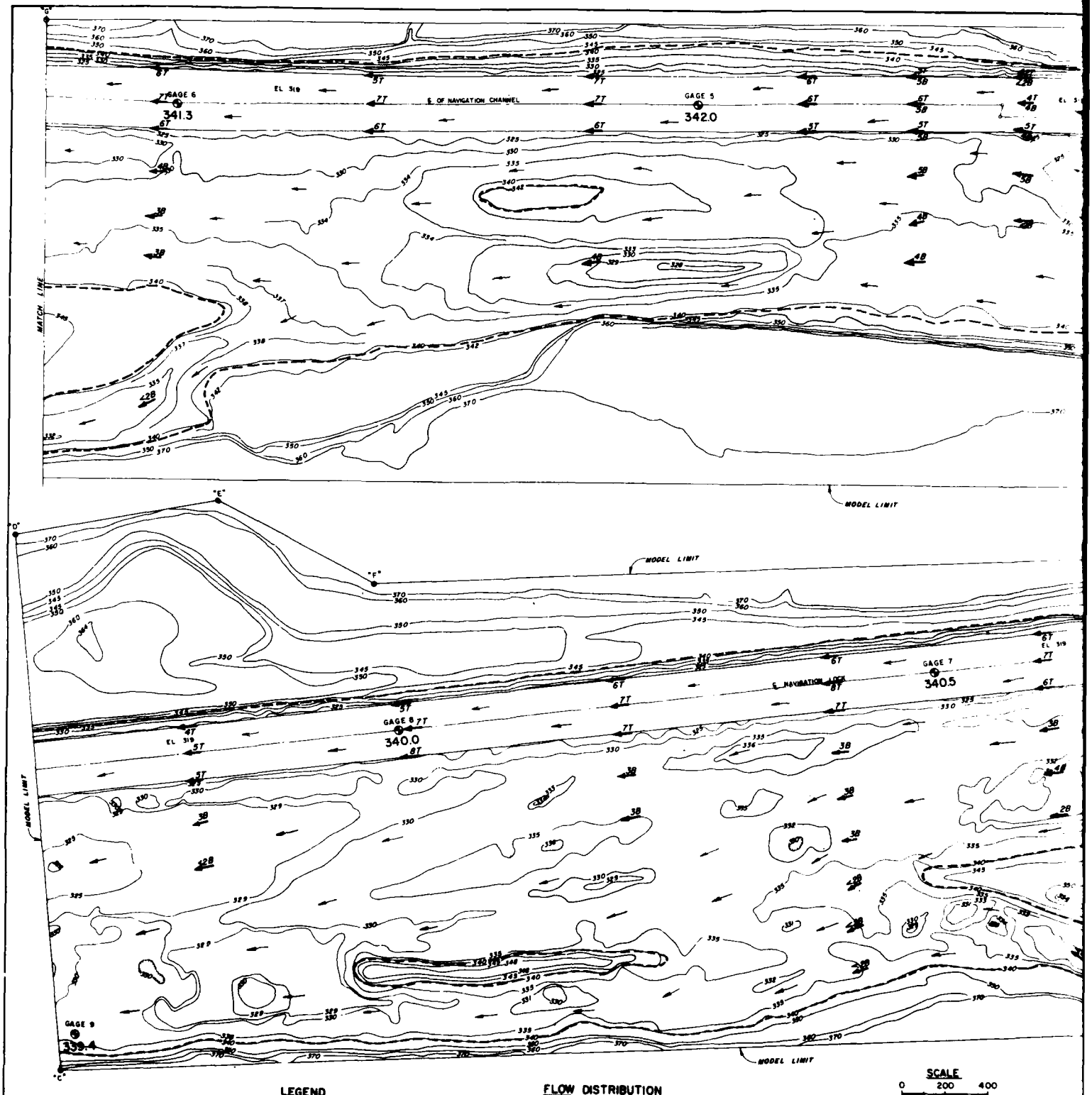
CLOSED
10 000 CFS

FLOW CONDITIONS EXISTING CHANNEL

RIVER DISCHARGE 10 000 CFS

McNARY POOL EL 335

PLATE 4



LEGEND

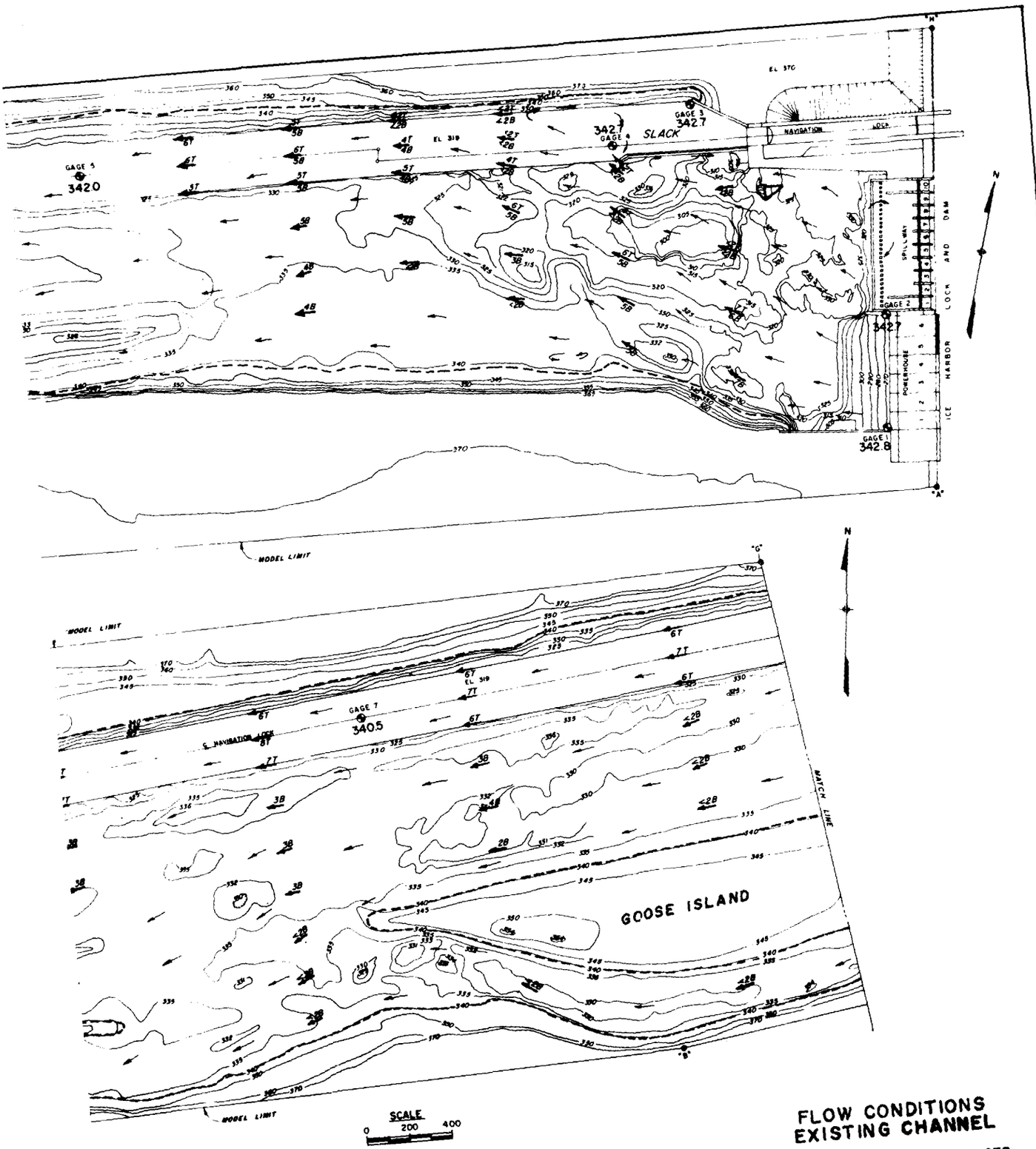
- 6 — VELOCITIES MEASURED IN FPS
- T — 7-FT DEPTH
- B — 5 FT OFF BOTTOM
- ← — FLOW DIRECTION

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNITS 1 TO 3	42 000 CFS
POWERHOUSE UNIT 4	18 000 CFS

SCALE

0 200 400



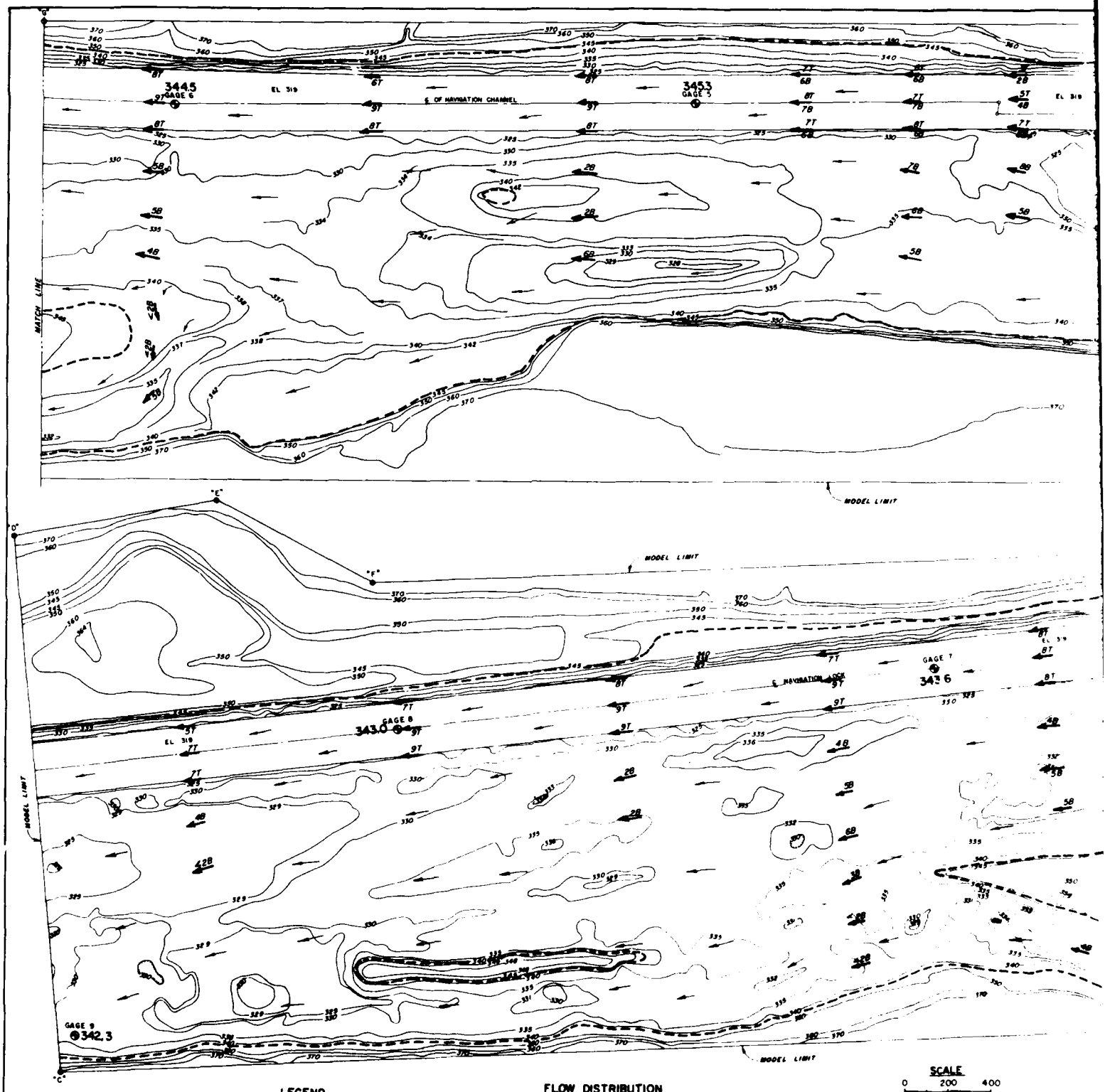
UTION

CLOSED
42 000 CFS
18 000 CFS

FLOW CONDITIONS
EXISTING CHANNEL

RIVER DISCHARGE 60 000 CFS
McNARY POOL EL 335

PLATE 5



LEGEND

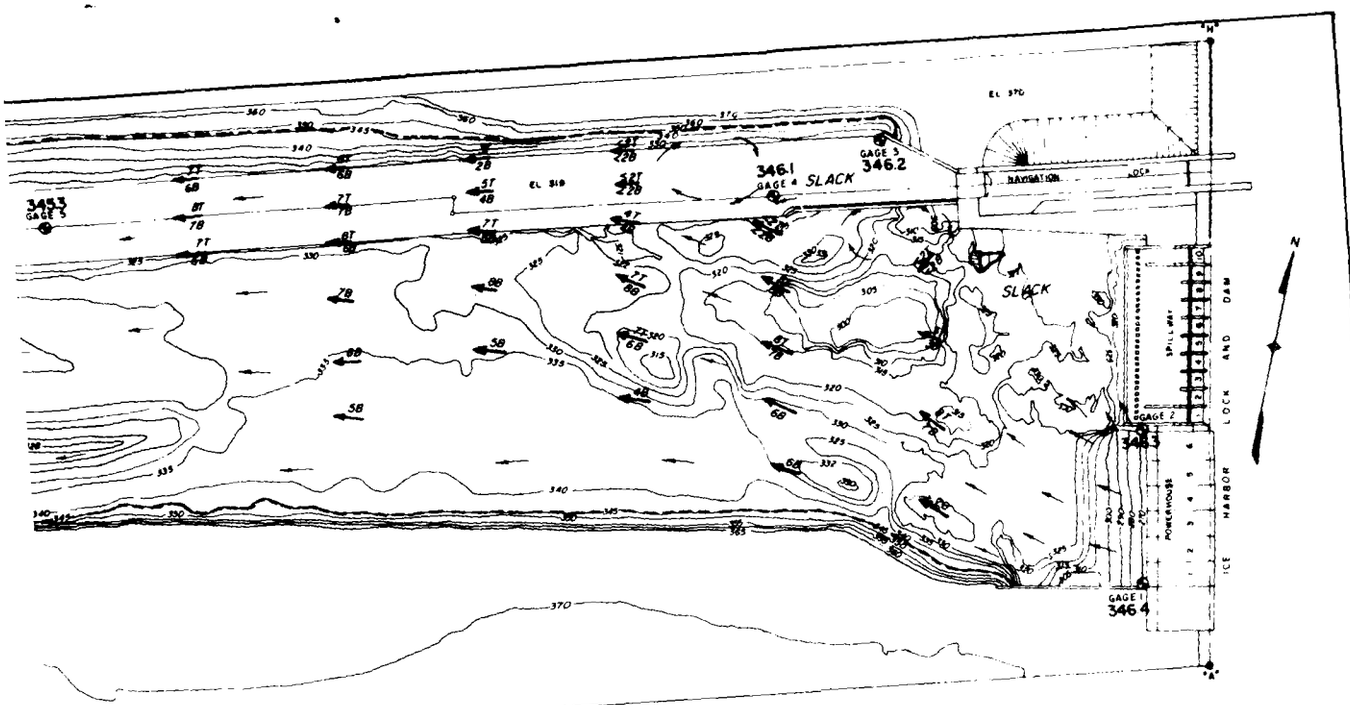
- 6 — VELOCITIES MEASURED IN FPS
- T — 7-FT DEPTH
- B — 5 FT OFF BOTTOM
- FLOW DIRECTION

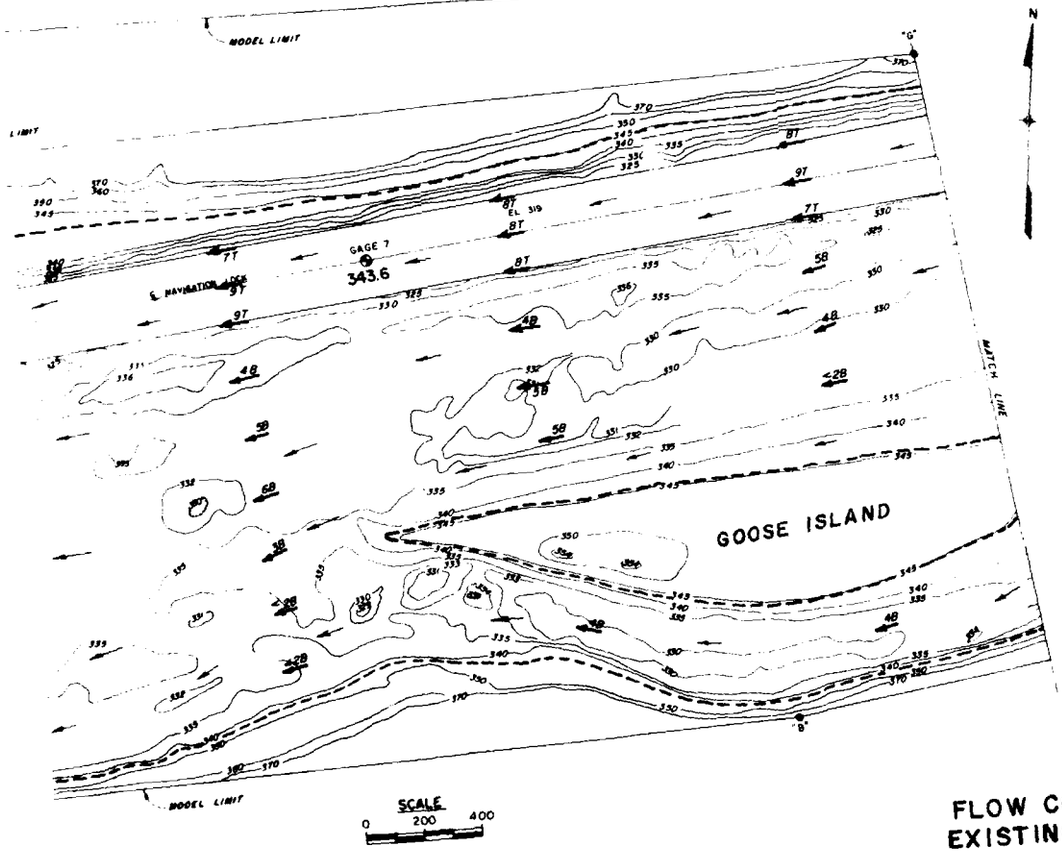
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

SCALE

0 200 400





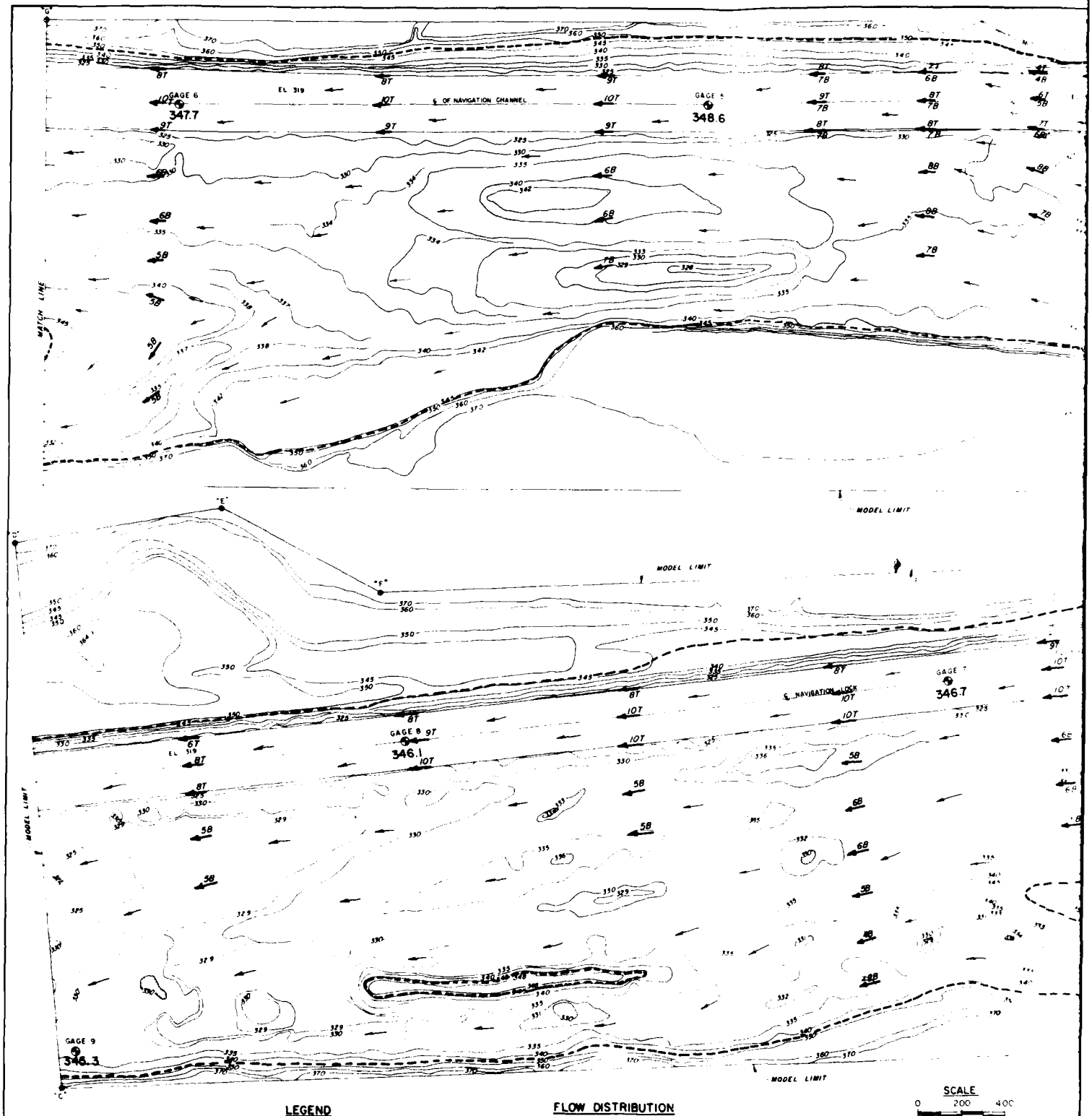
SCALE
0 200 400

CLOSED
300 CFS
700 CFS

FLOW CONDITIONS
EXISTING CHANNEL

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 6



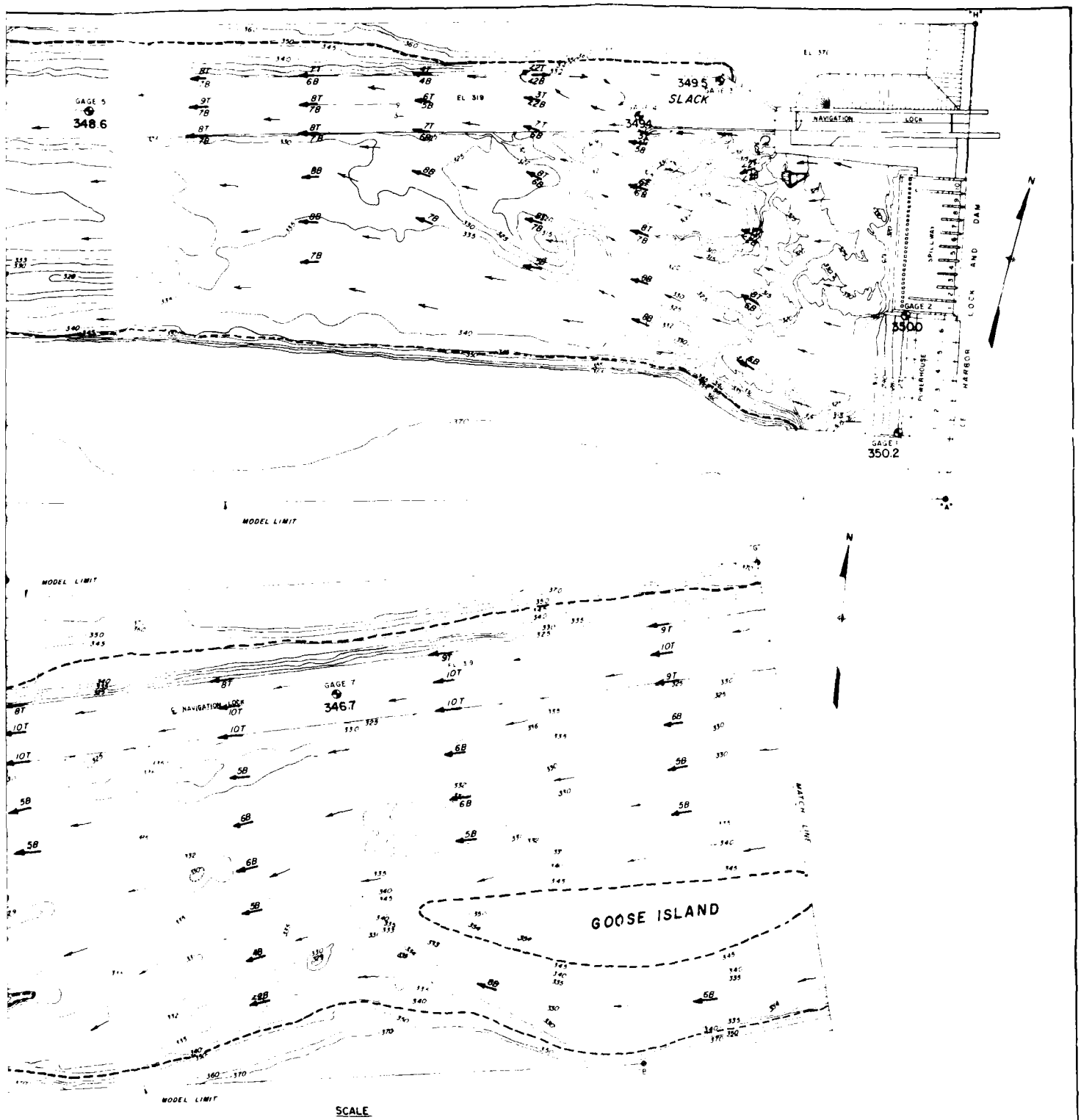
LEGEND

- 6 VELOCITIES MEASURED IN FPS
- T 7-FT DEPTH
- B 5 FT OFF BOTTOM
- FLOW DIRECTION

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000 CFS
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

SCALE
0 200 400



SCALE
0 200 400

RIBUTION

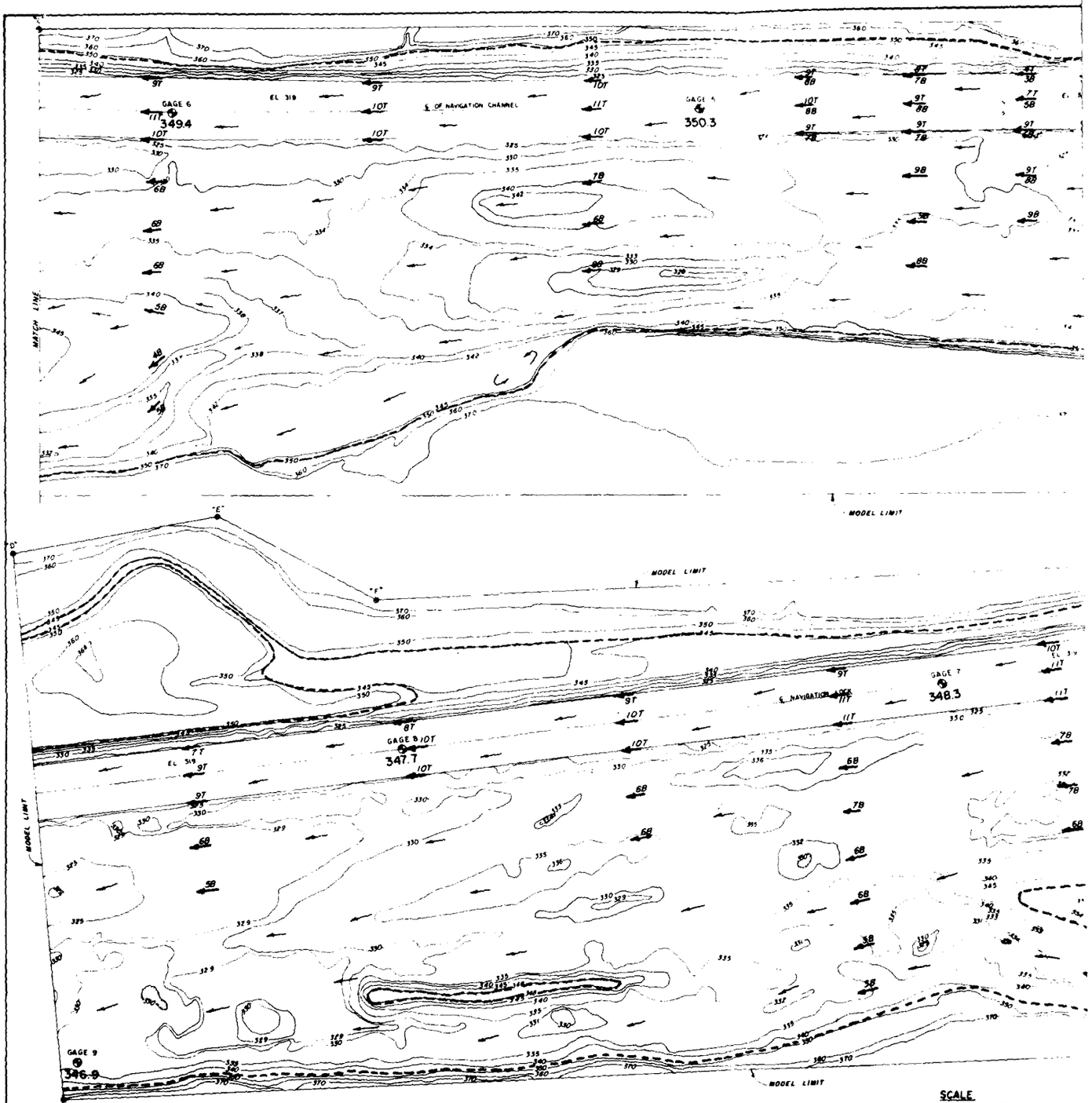
50 000 CFS
3 43 300 CFS
6 56 700 CFS

FLOW CONDITIONS
EXISTING CHANNEL

RIVER DISCHARGE 150 000 CFS

McNARY POOL EL 335

PLATE 7

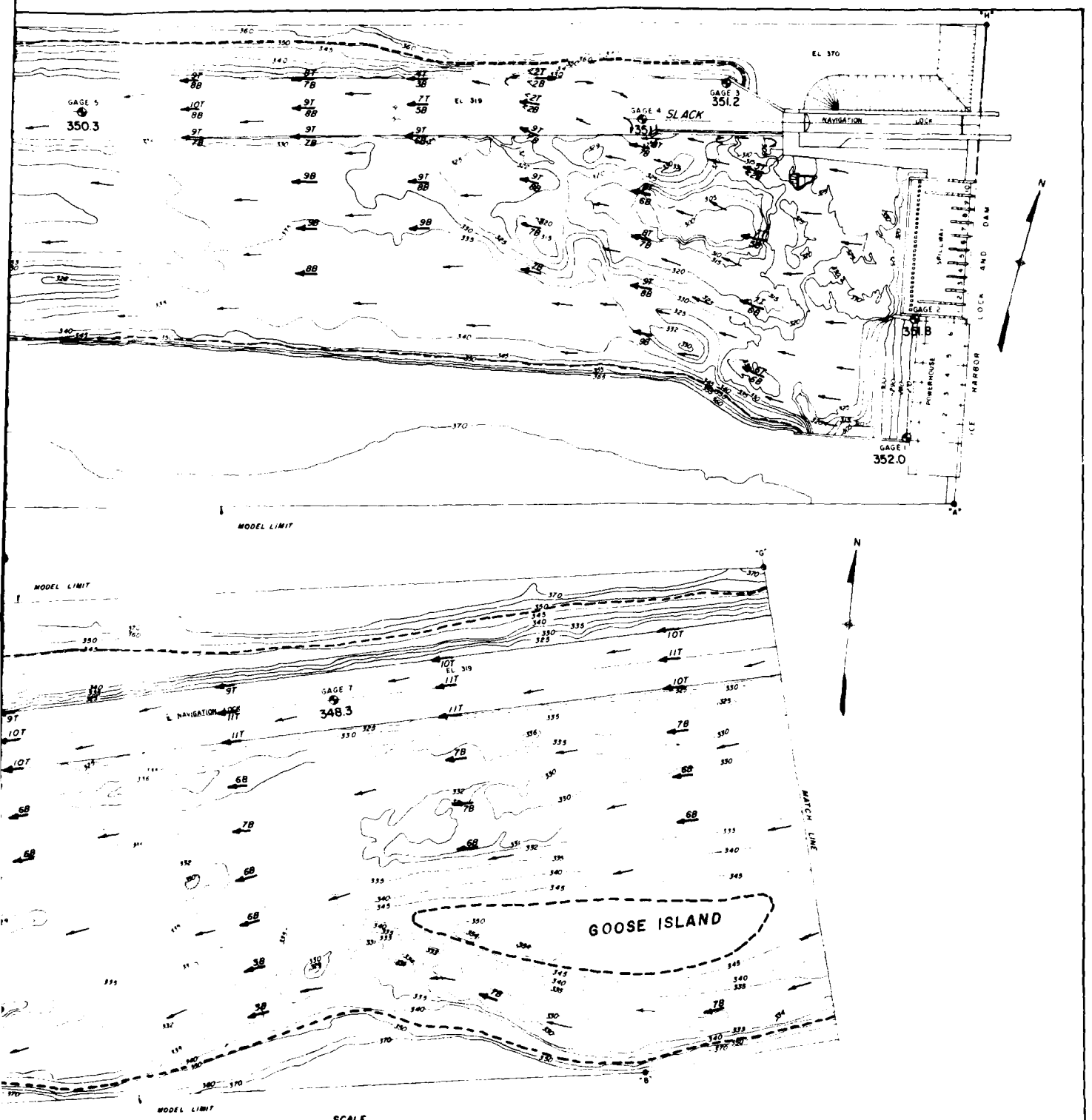


LEGEND

- 6 VELOCITIES MEASURED IN FPS
- T 7-FT DEPTH
- B 5 FT OFF BOTTOM
- FLOW DIRECTION

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	79 500 CFS
POWERHOUSE UNITS 1 TO 3	44 400 CFS
POWERHOUSE UNITS 4 TO 6	56 100 CFS



SCALE
0 200 400

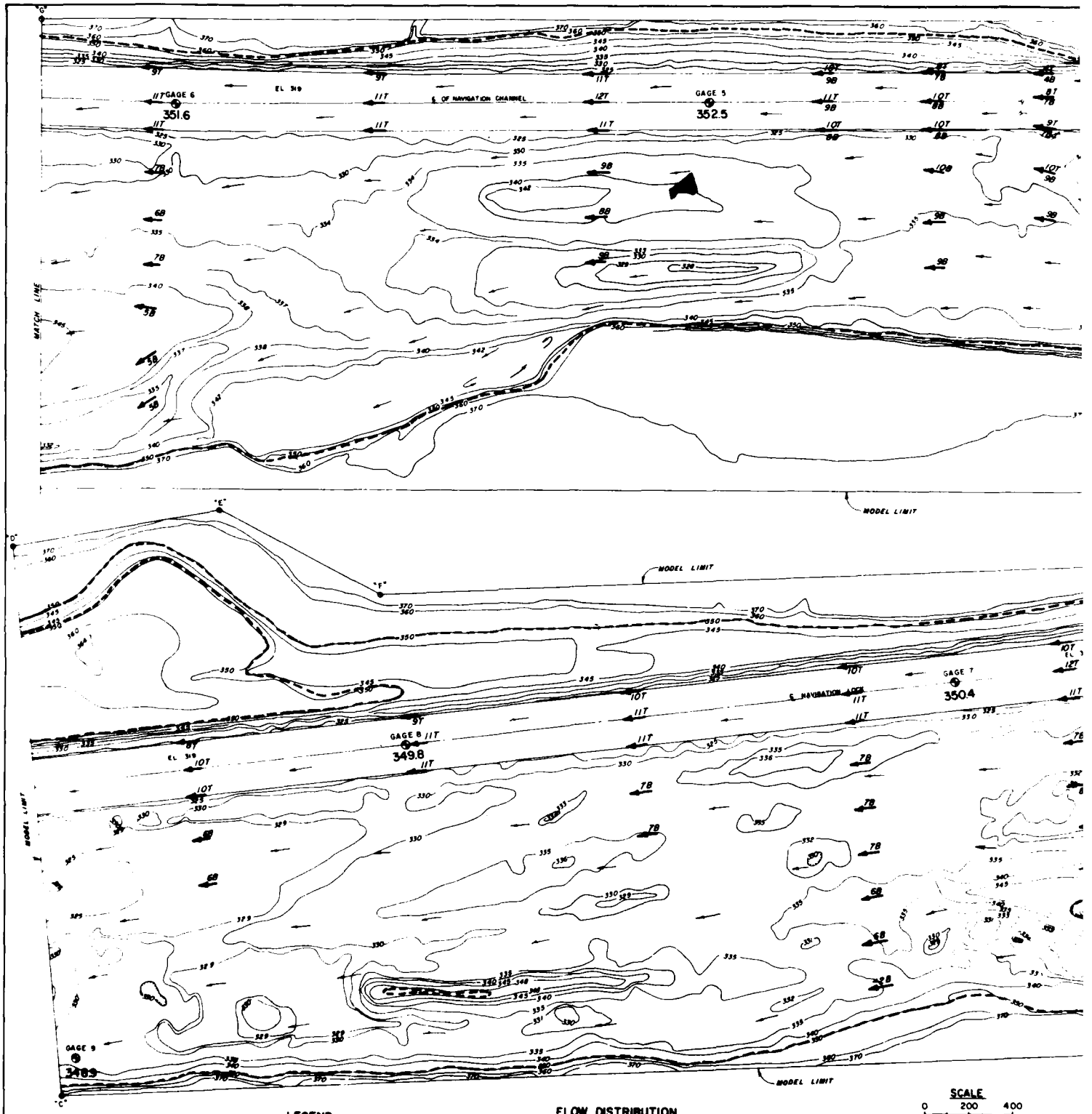
RIBUTION

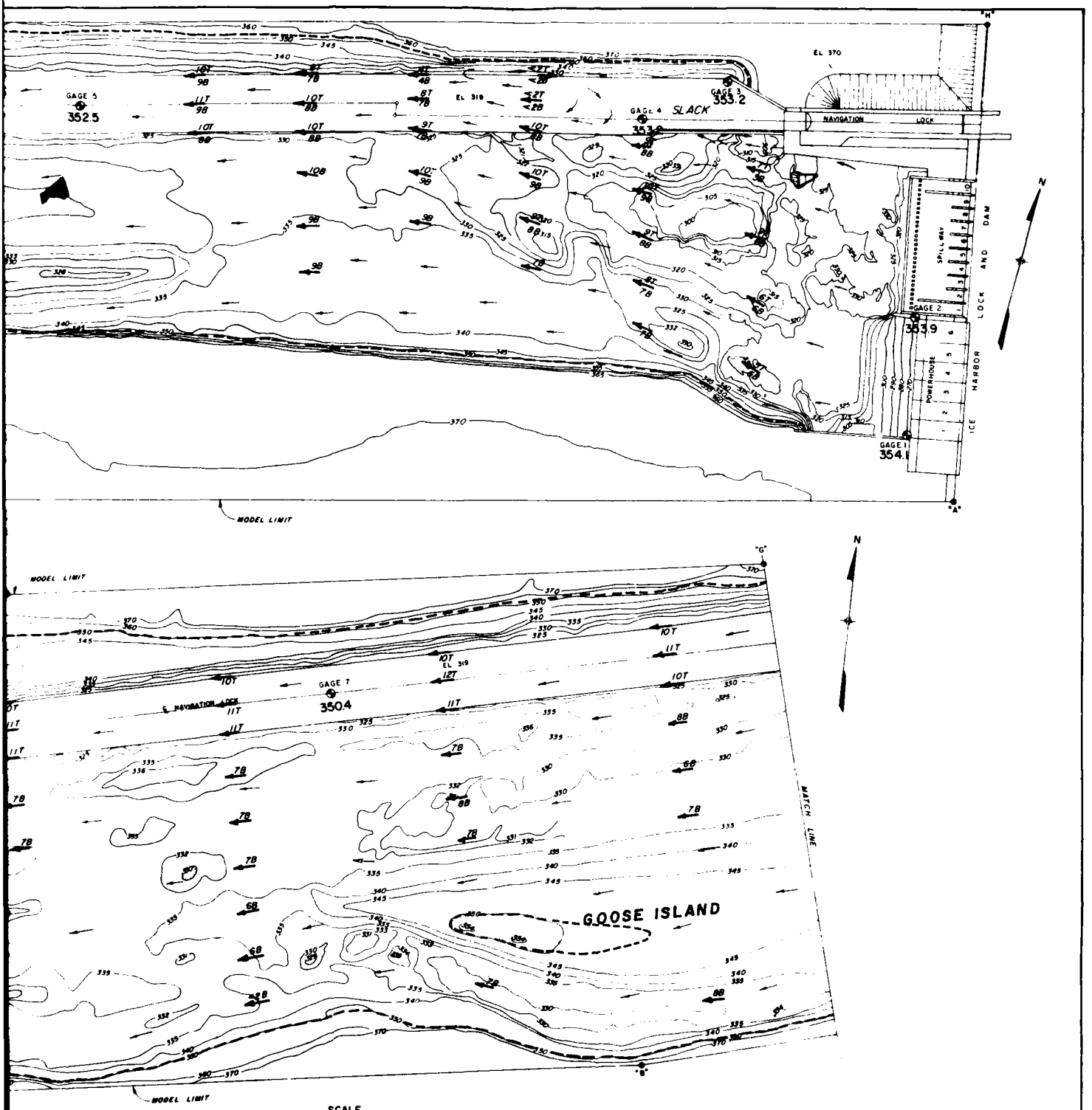
79 500 CFS
44 400 CFS
56 100 CFS

FLOW CONDITIONS
EXISTING CHANNEL

RIVER DISCHARGE 180 000 CFS
McNARY POOL EL 335

PLATE 8


GAGE 6
351.6
GAGE 5
352.5
EL 310
℄ OF NAVIGATION CHANNEL
MATCH LINE
MODEL LIMIT
GAGE 8
349.8
GAGE 7
350.4
℄ NAVIGATION LOCK
GAGE 9
348.3
LEGEND
6 VELOCITIES MEASURED IN FPS
T 7-FT DEPTH
B 5 FT OFF BOTTOM
FLOW DIRECTION
FLOW DISTRIBUTION
SPILLWAY BAYS 1 TO 10 119 200 CFS
POWERHOUSE UNITS 1 TO 3 45 300 CFS
POWERHOUSE UNITS 4 TO 6 55 500 CFS
SCALE
0 200 400



UTION

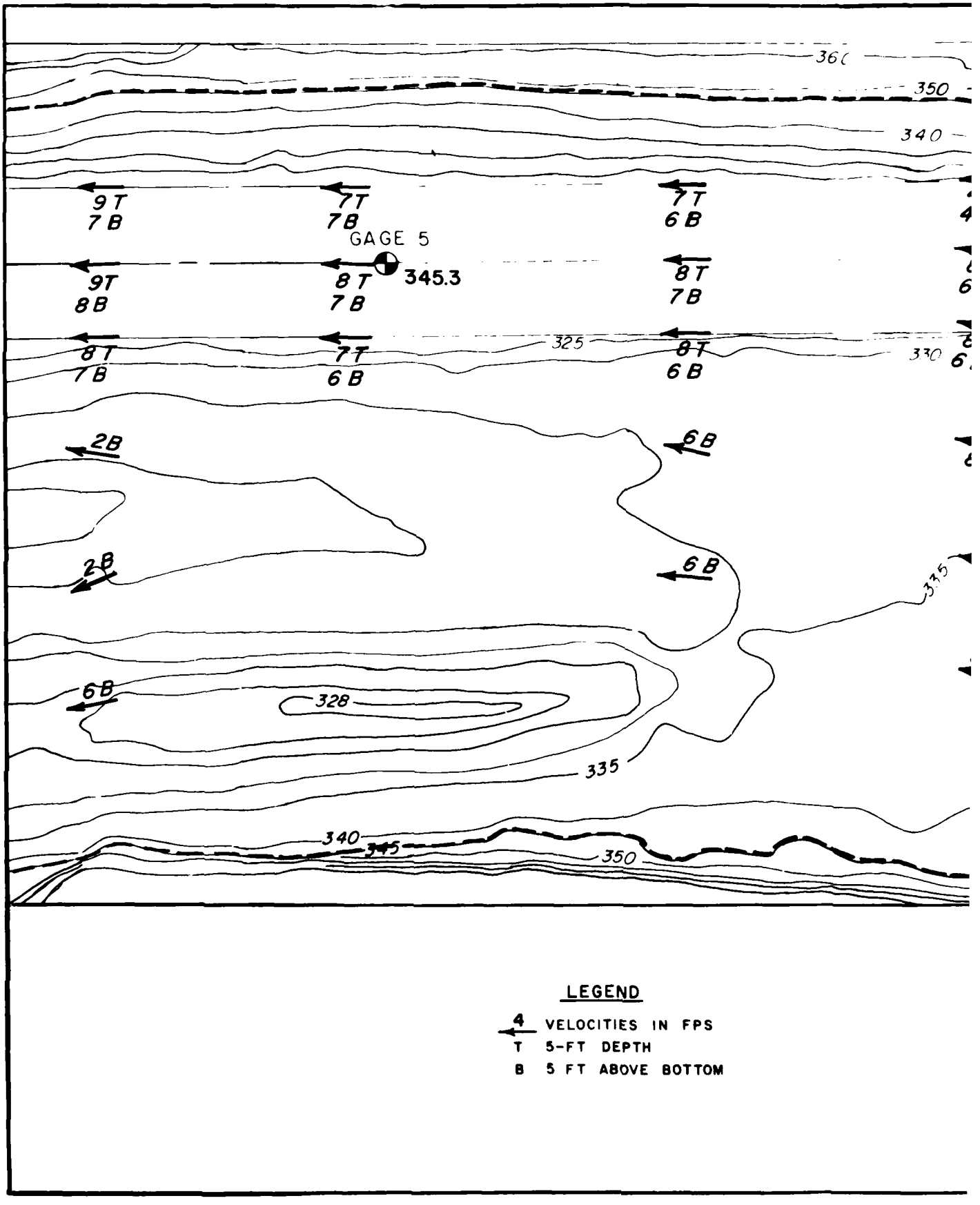
	119 200 CFS
3	45 300 CFS
	55 500 CFS

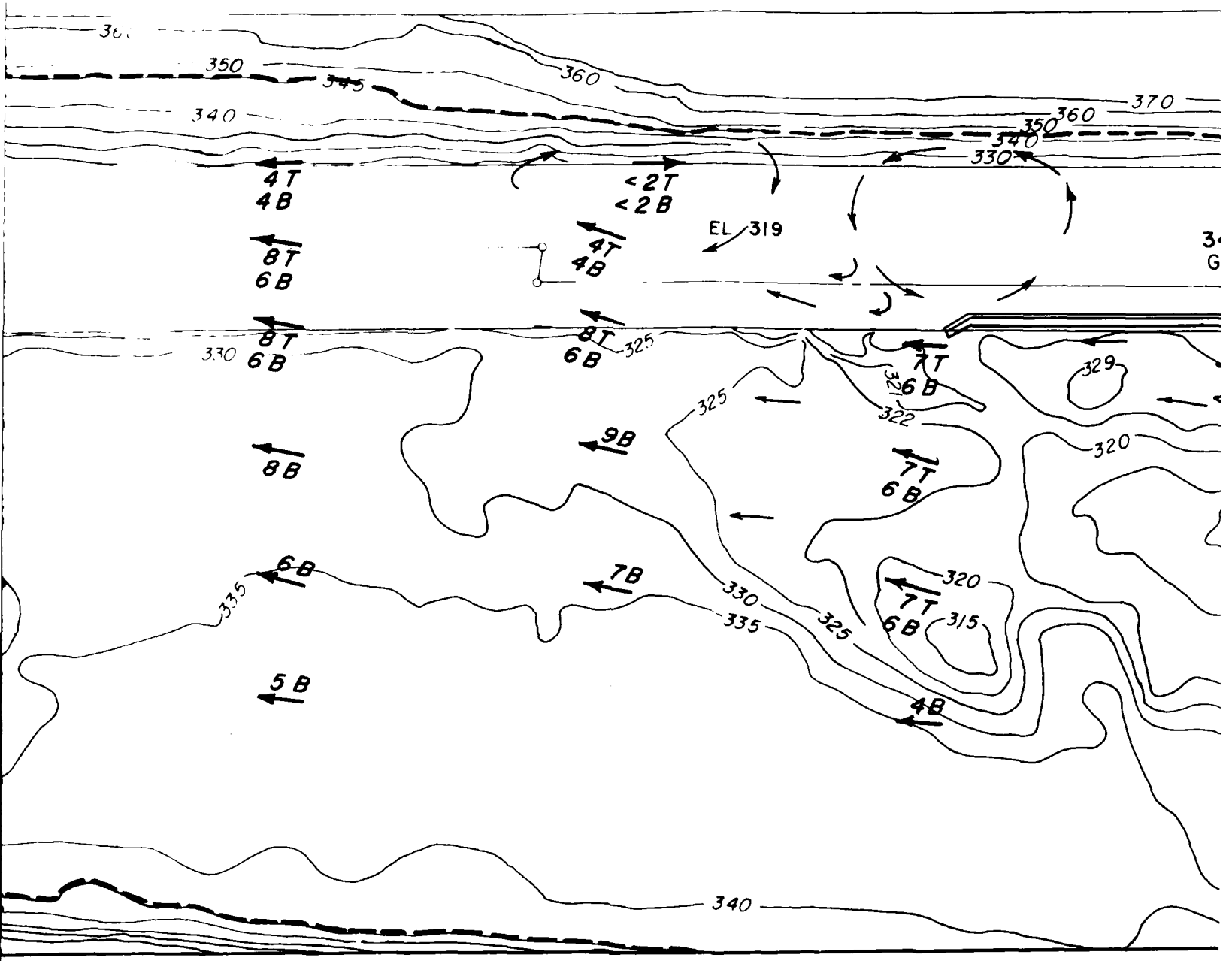
FLOW CONDITIONS
EXISTING CHANNEL

RIVER DISCHARGE 220 000 CFS

McNARY POOL EL 335

PLATE 9


360
350
340
9T
7B
7T
7B
7T
6B
GAGE 5
345.3
9T
8B
8T
7B
8T
7B
8T
7B
7T
6B
8T
6B
325
330
2B
6B
2B
6B
335
6B
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

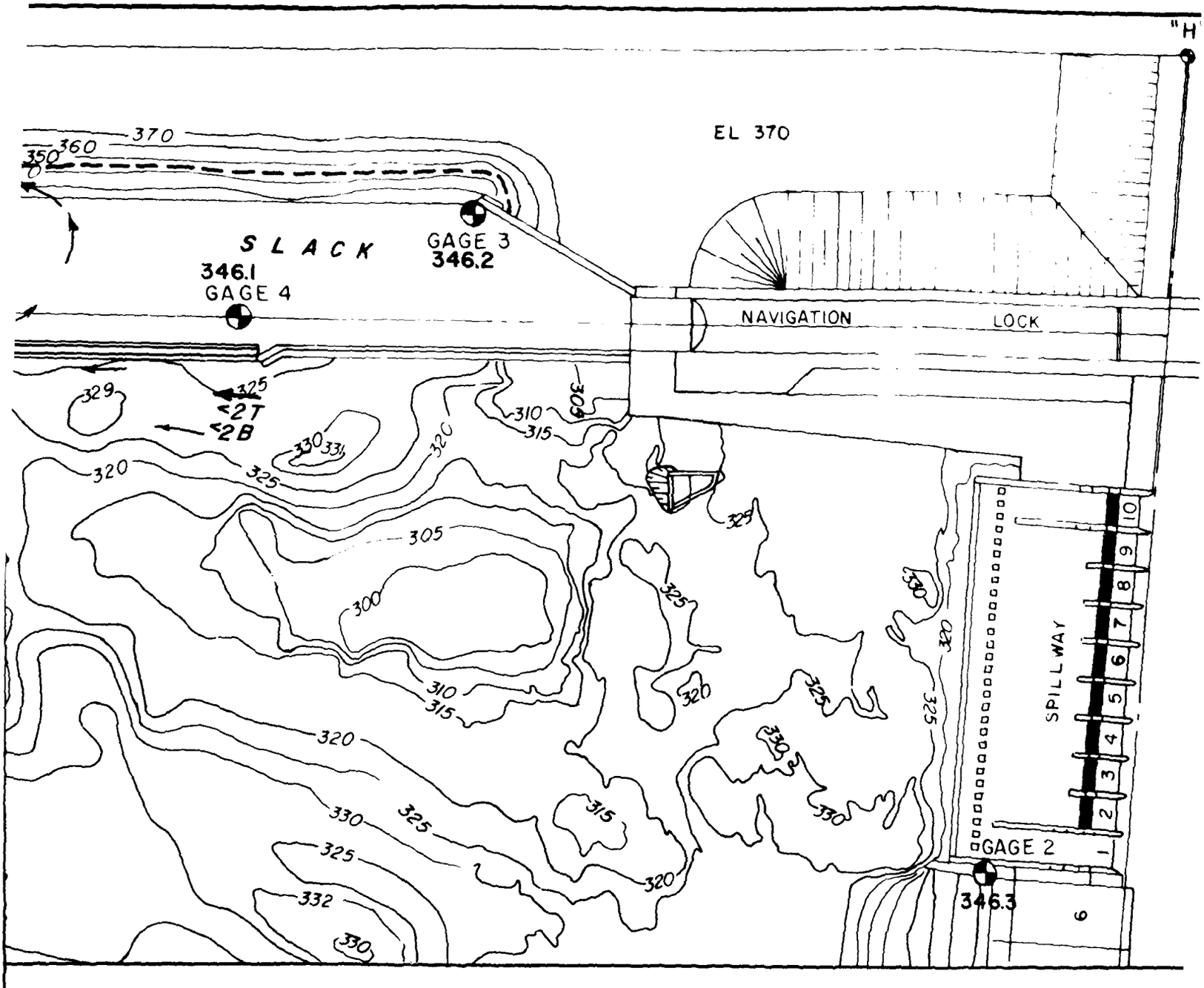
0 100 200 300 400 500 FT

FLOW DISTRI

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



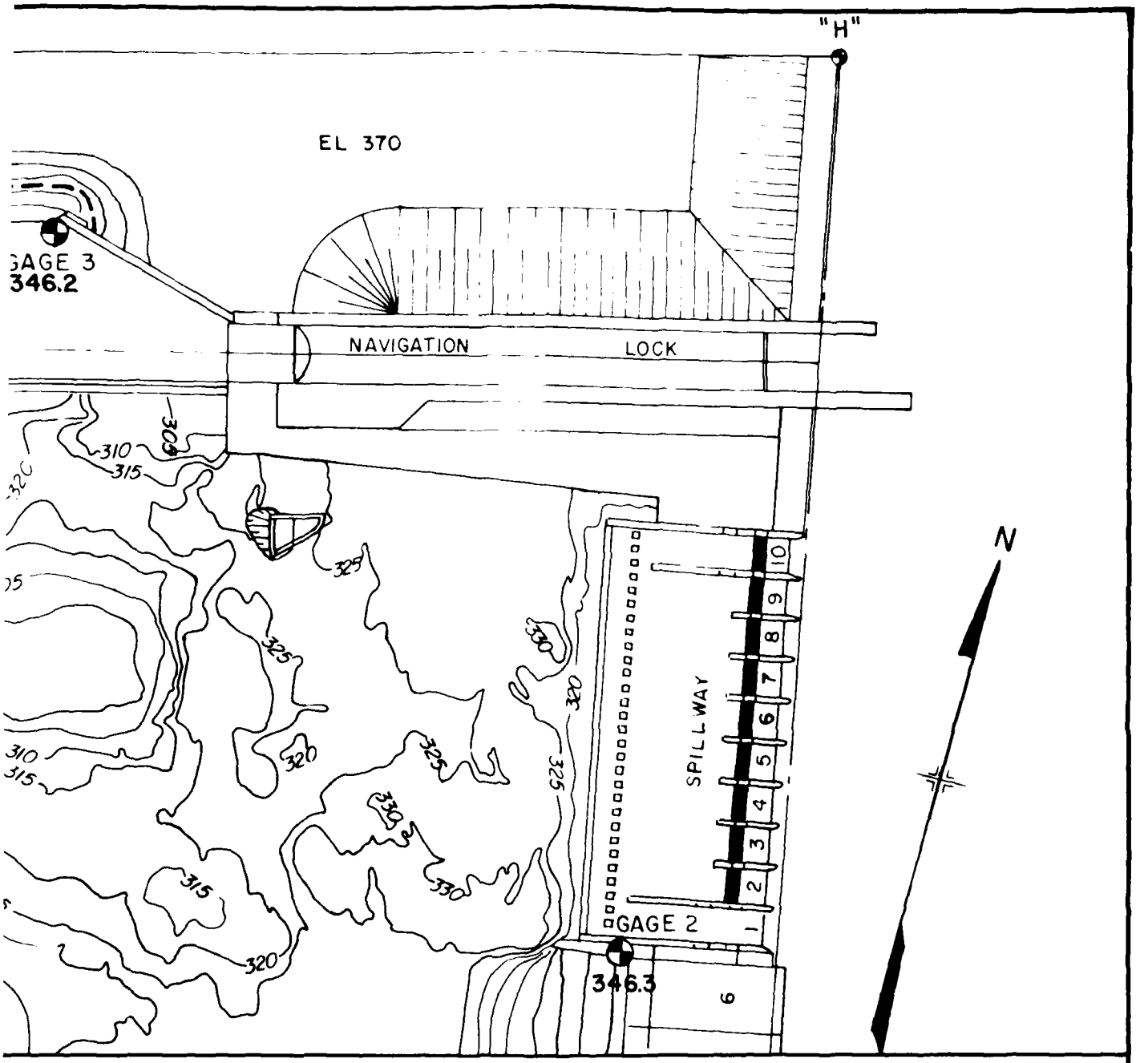
FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
USE UNITS 1 TO 3	43 300 CFS
USE UNITS 4 TO 6	56 700 CFS

500-FT W

FLOW (

RIVER DISCH
McNARY

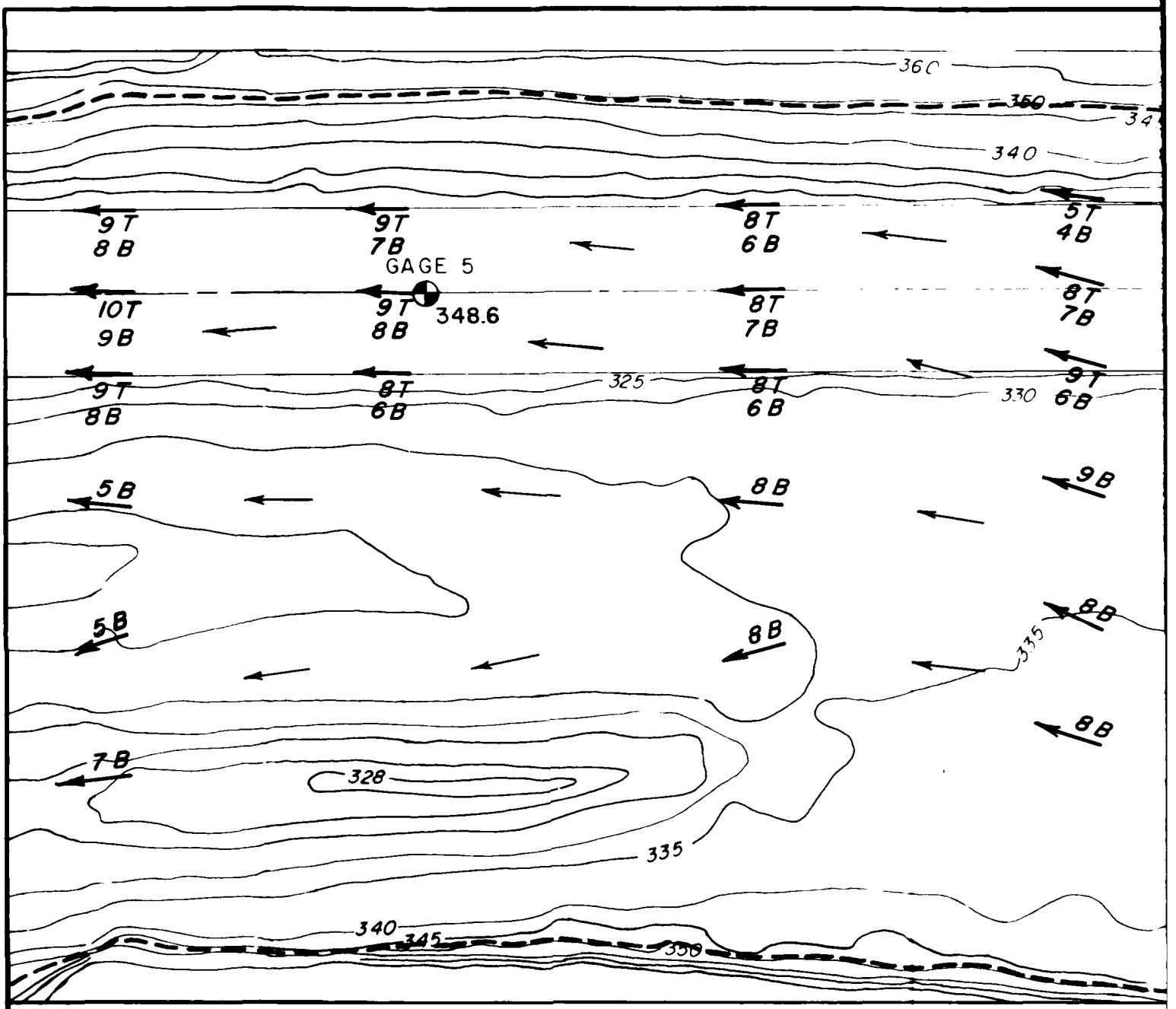


500-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 10

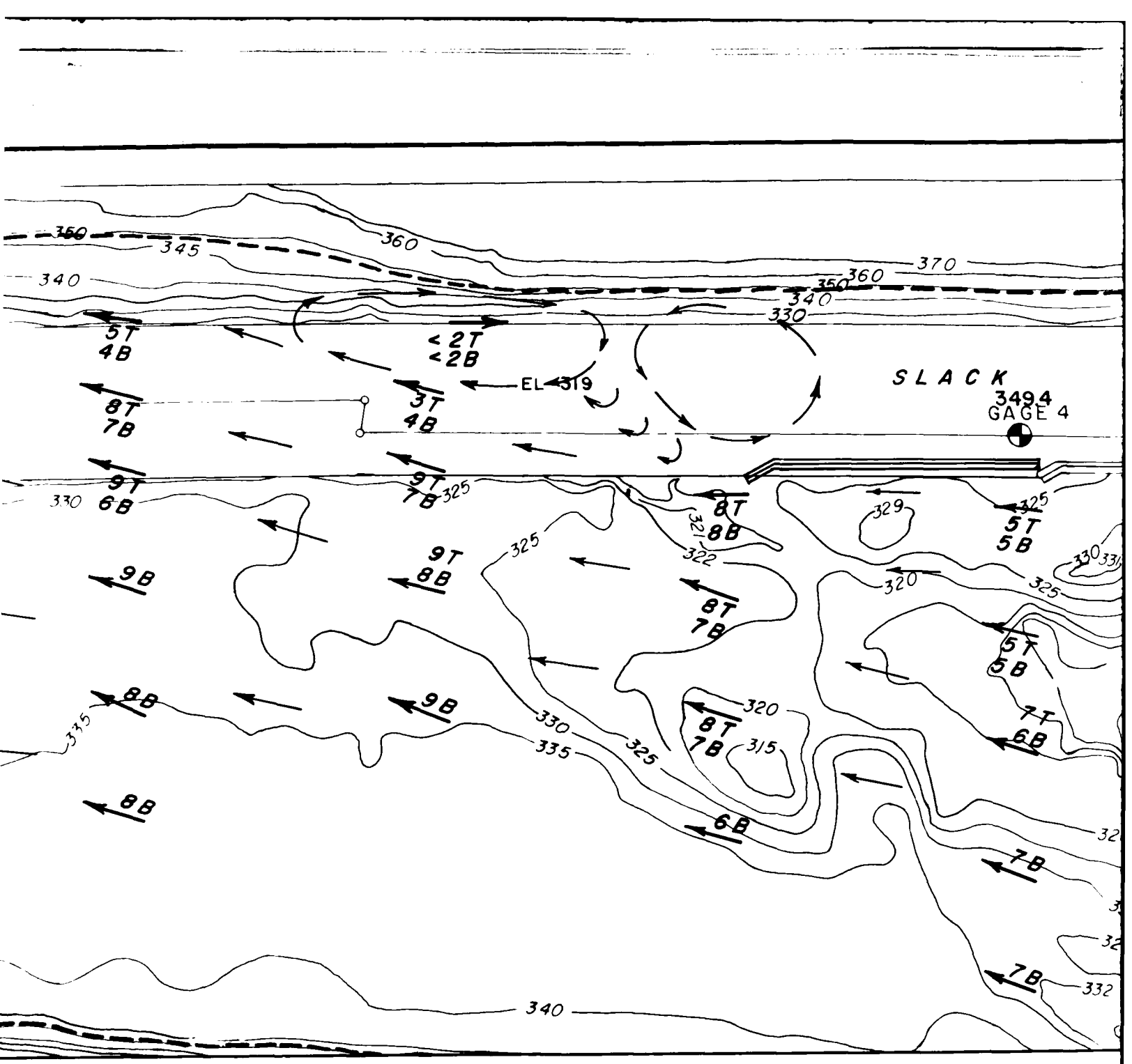


LEGEND

4 VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



SCALE

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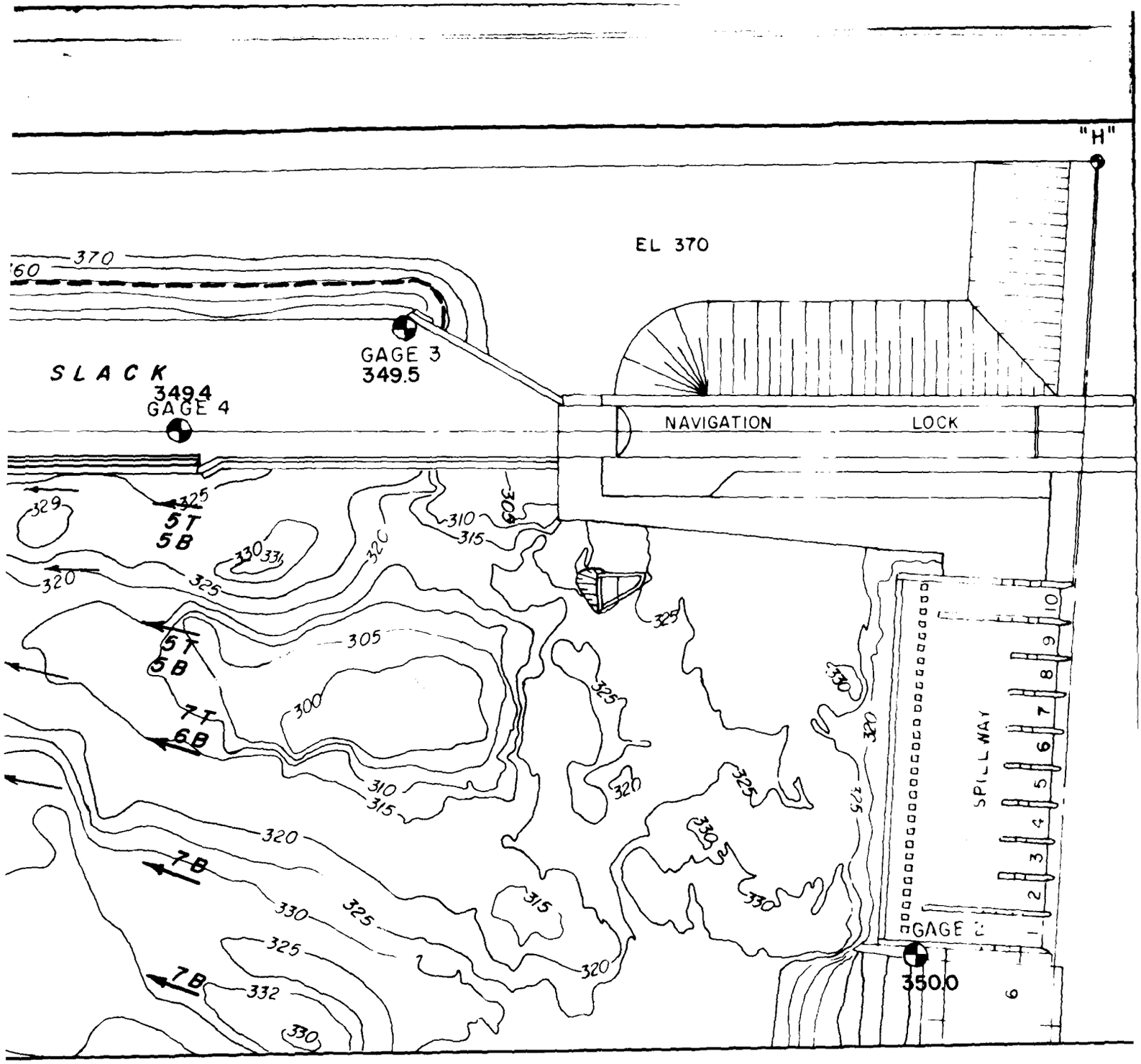
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000
POWERHOUSE UNITS 1 TO 3	43 300
POWERHOUSE UNITS 4 TO 6	56 700



500-FT WAL

FLOW DISTRIBUTION

YS 1 TO 10	50 000	CFS
UNITS 1 TO 3	43 300	CFS
UNITS 4 TO 6	56 700	CFS

FLOW CO

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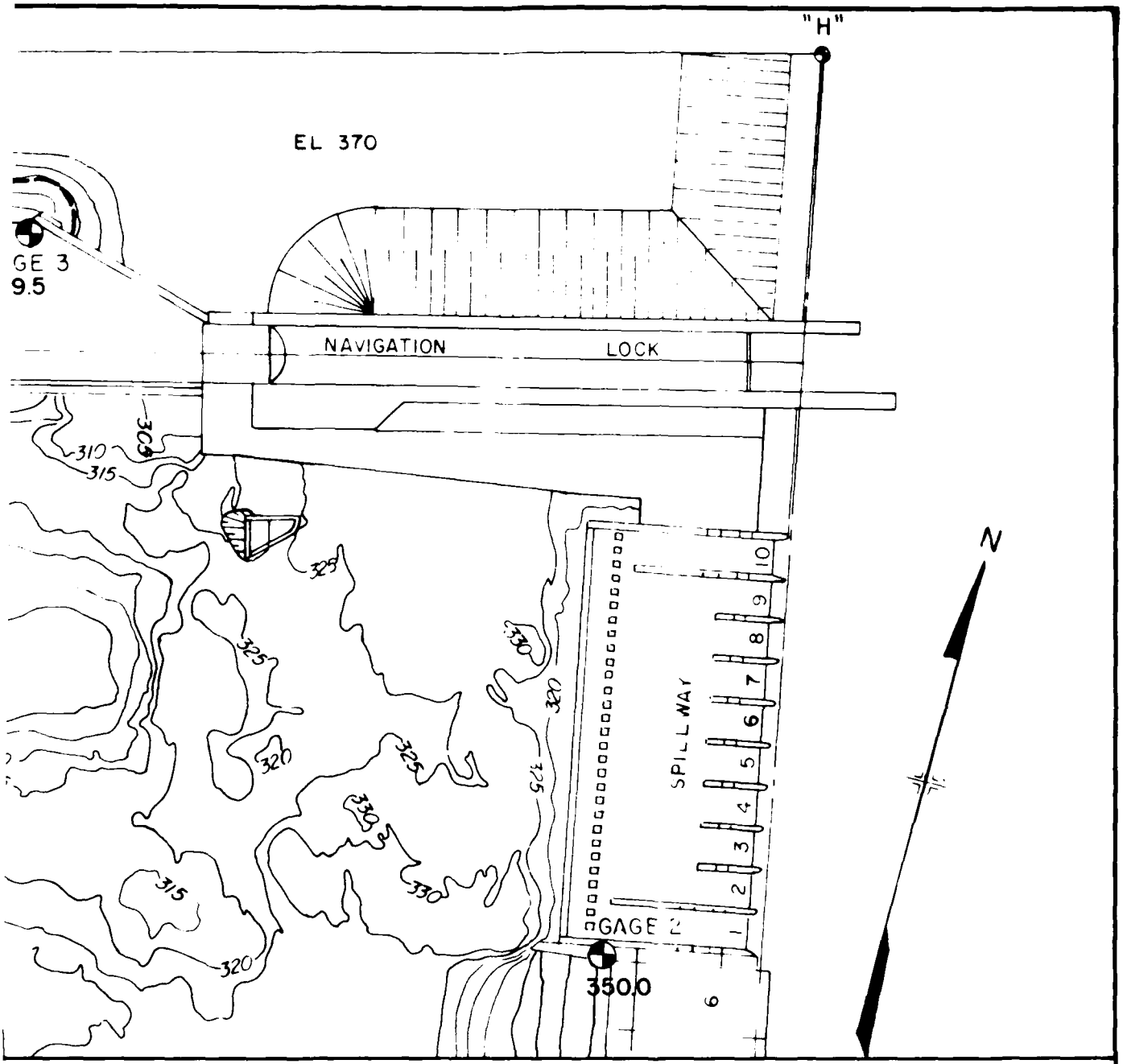
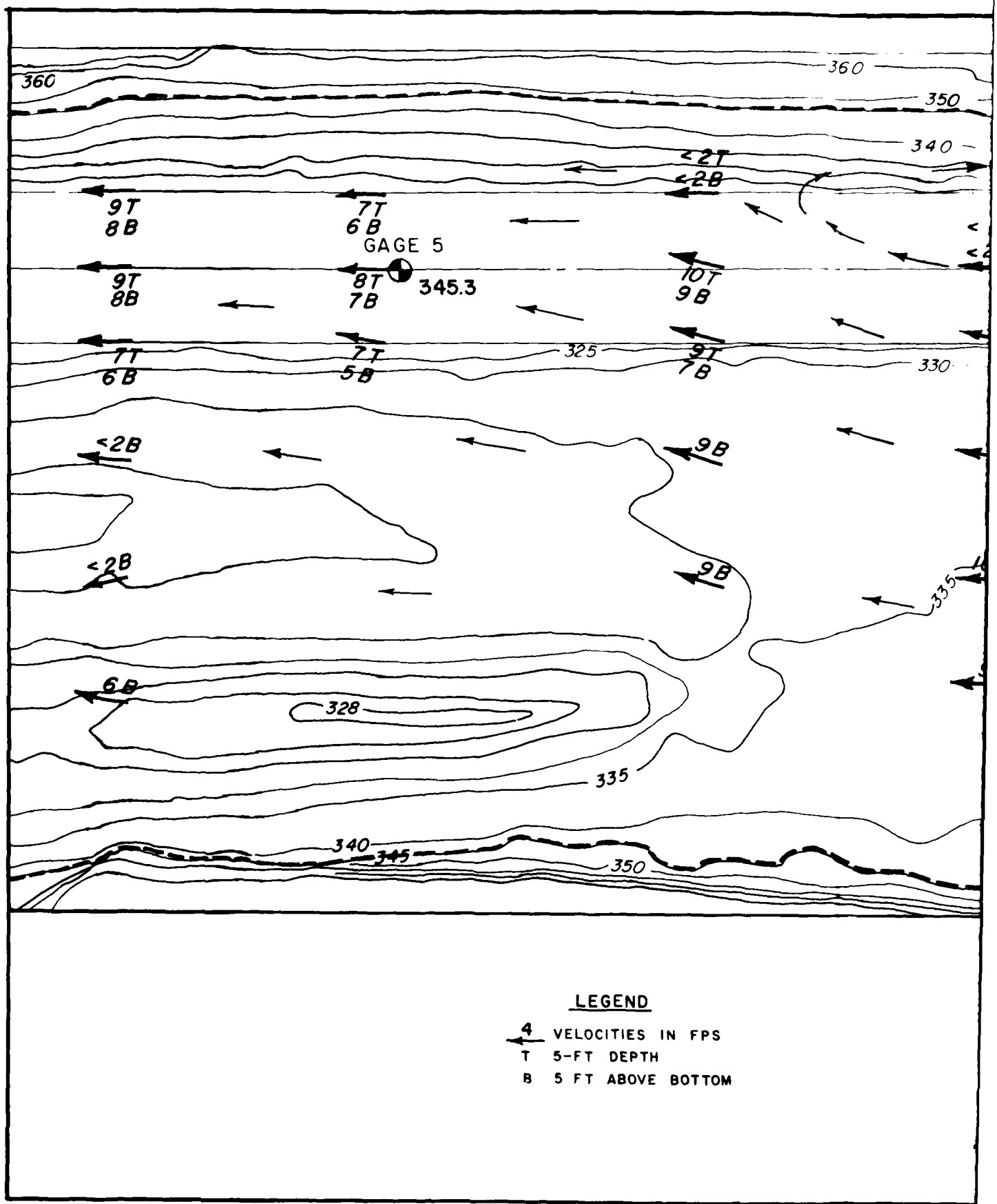


500-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 150000 CFS
McNARY POOL EL 335

PLATE 11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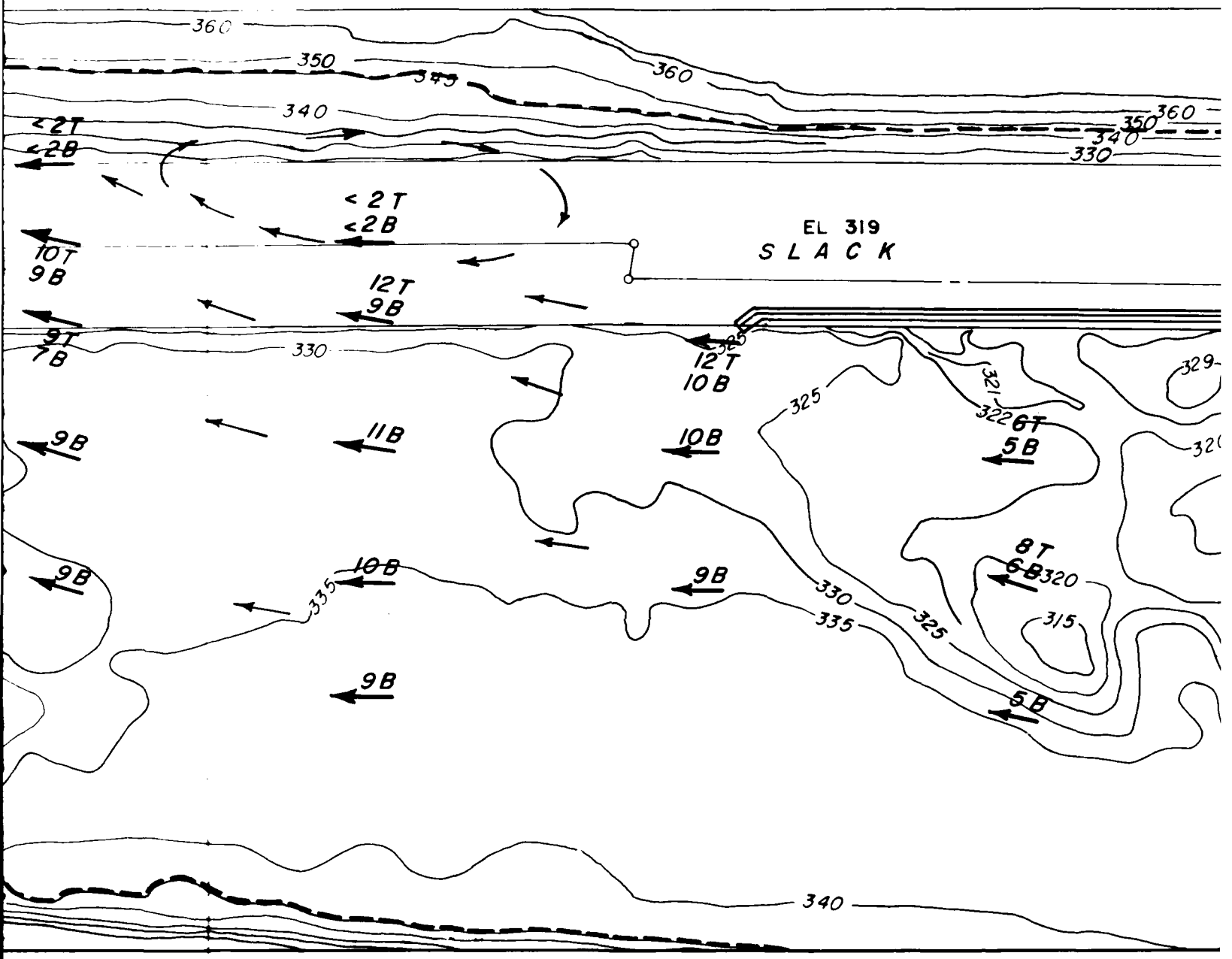
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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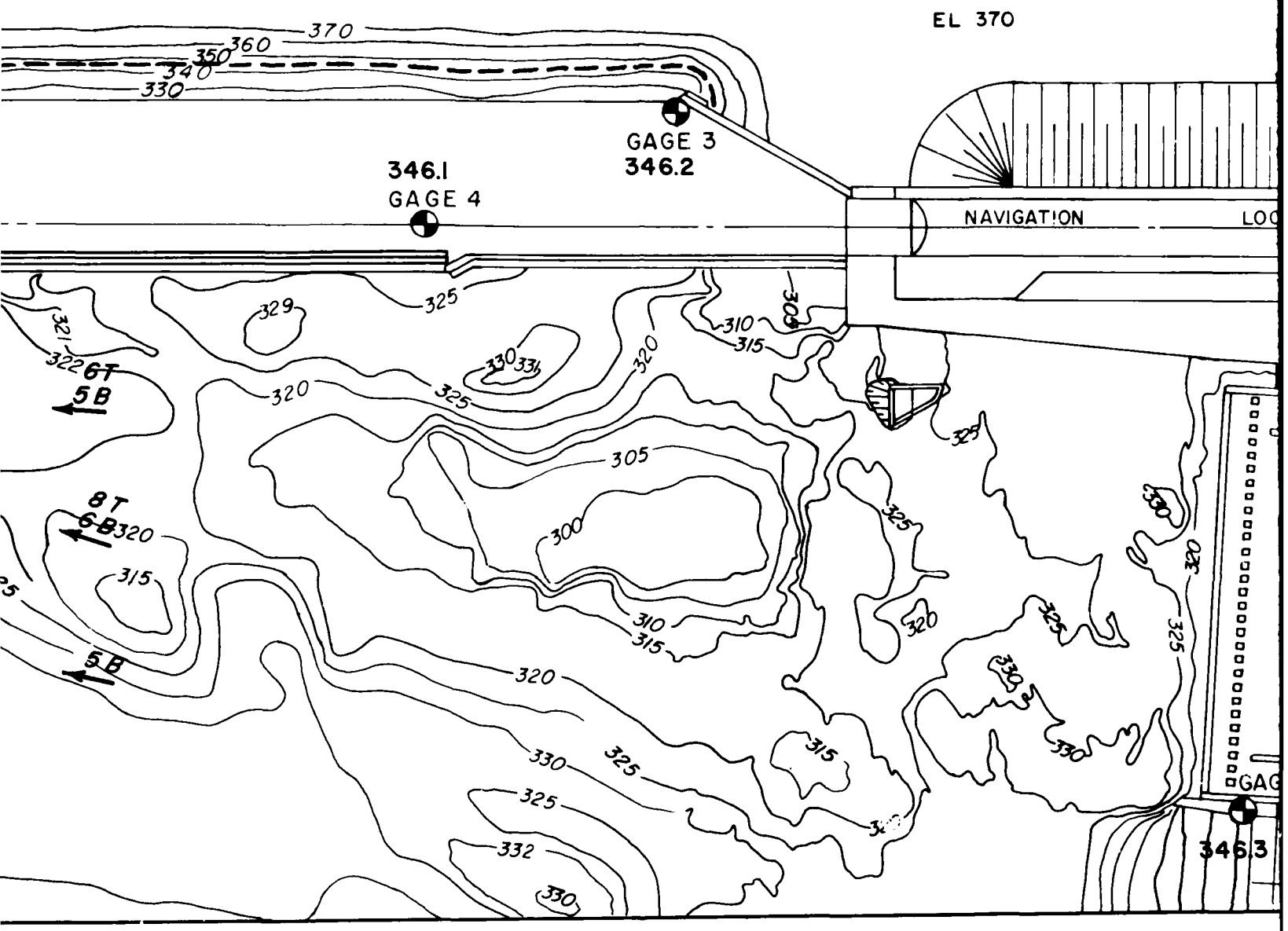
SPILLWAY BAYS I T

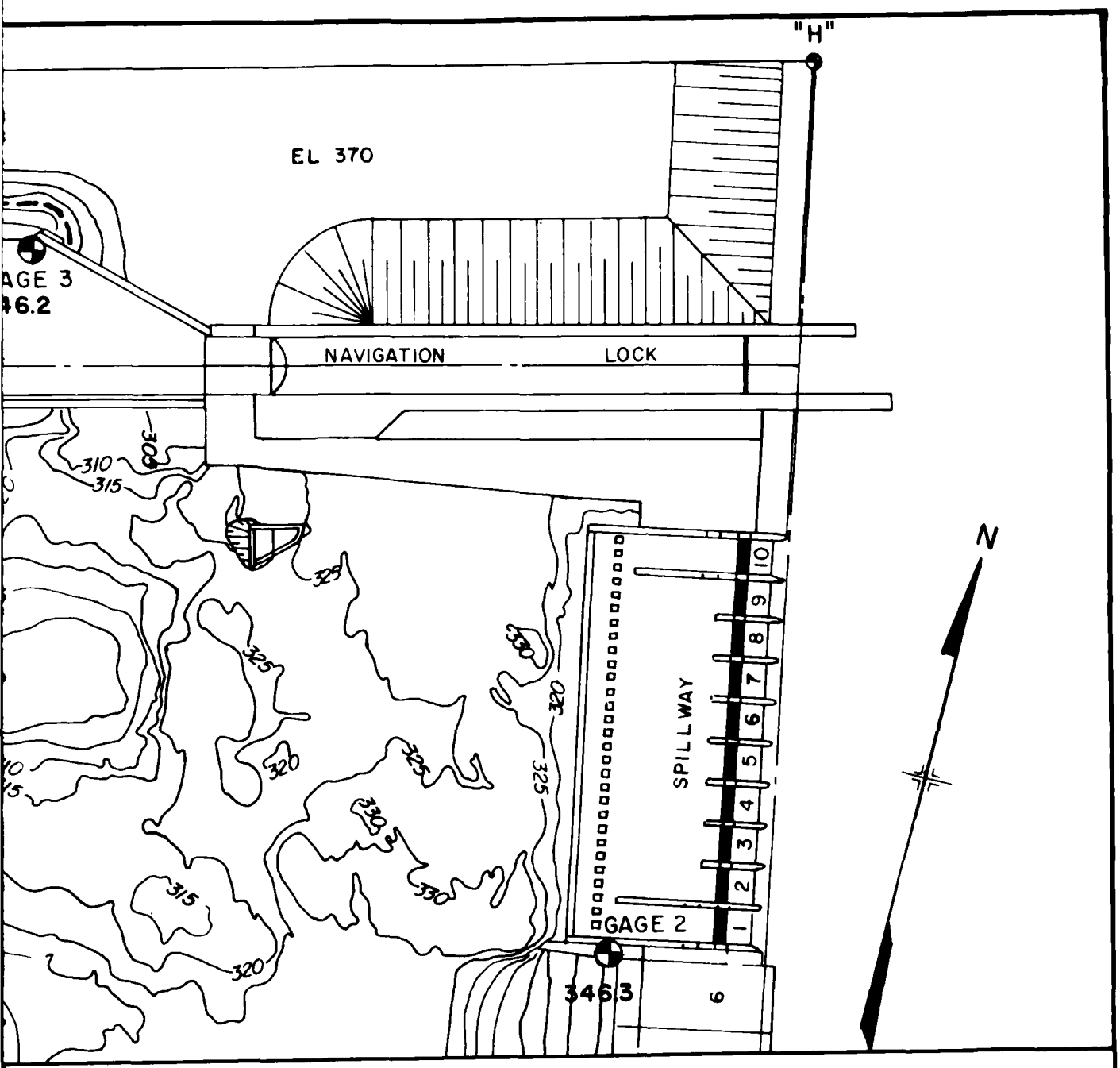
POWERHOUSE UNITS

POWERHOUSE UNITS



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

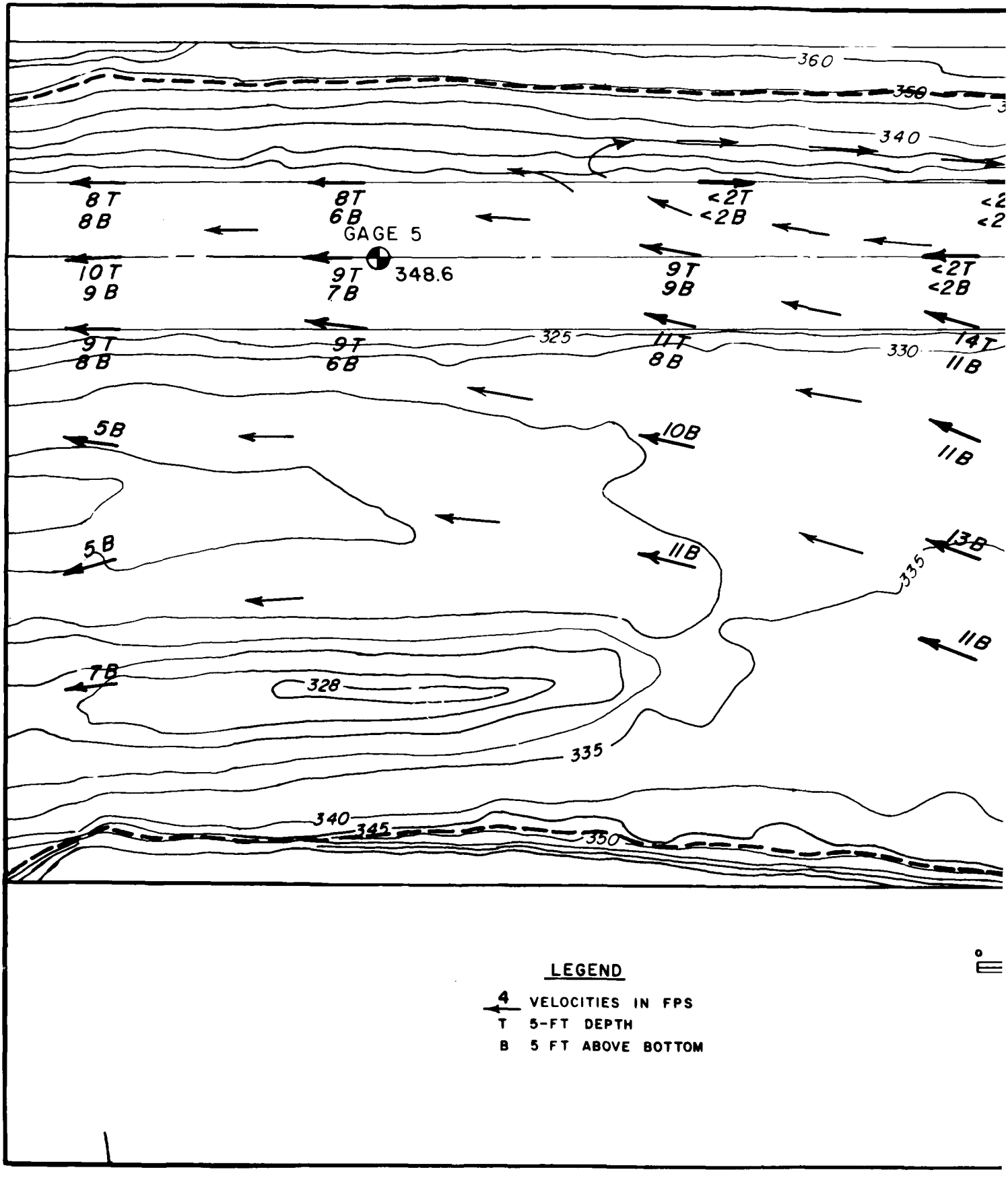


1000-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 12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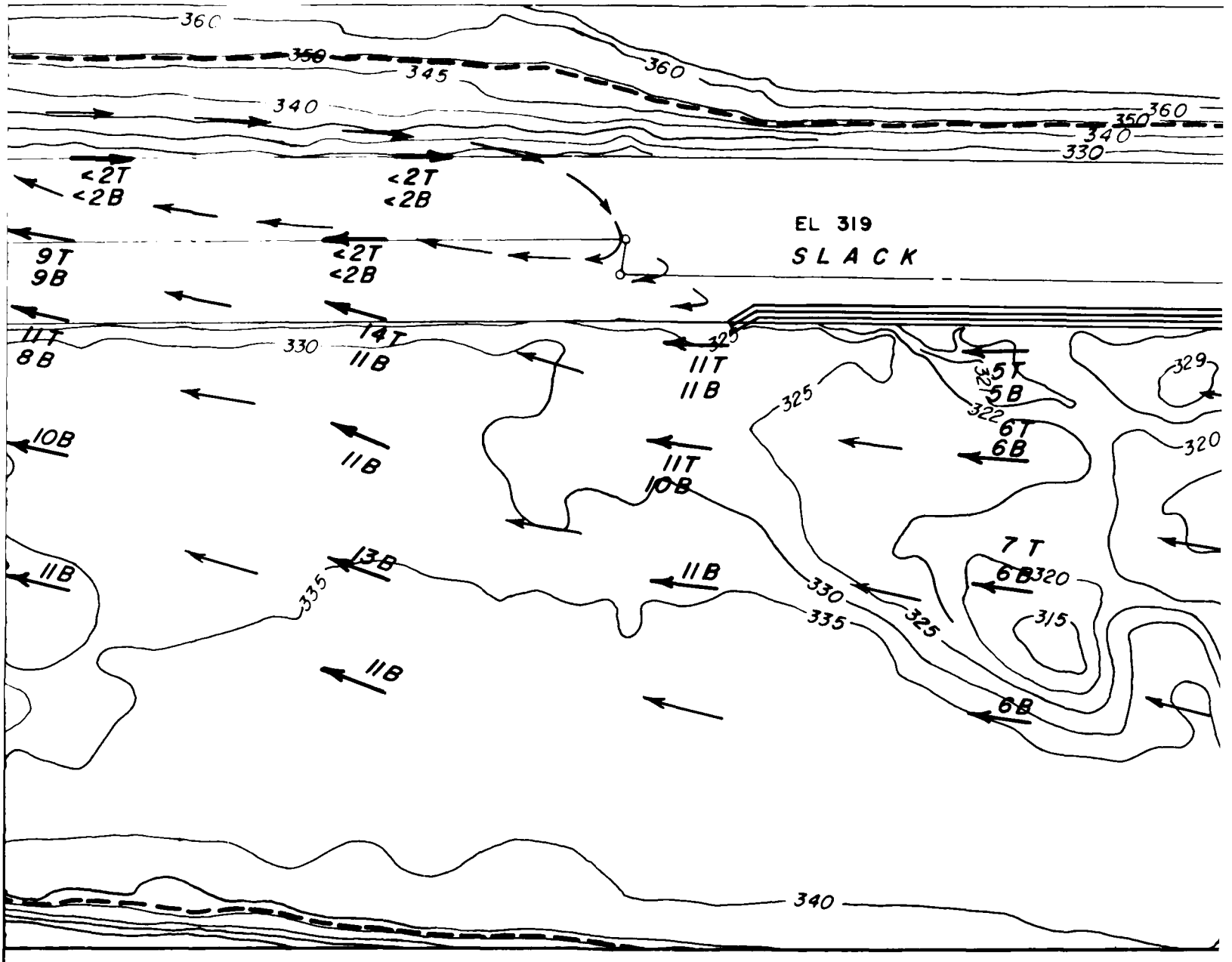
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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FLOW

N FPS

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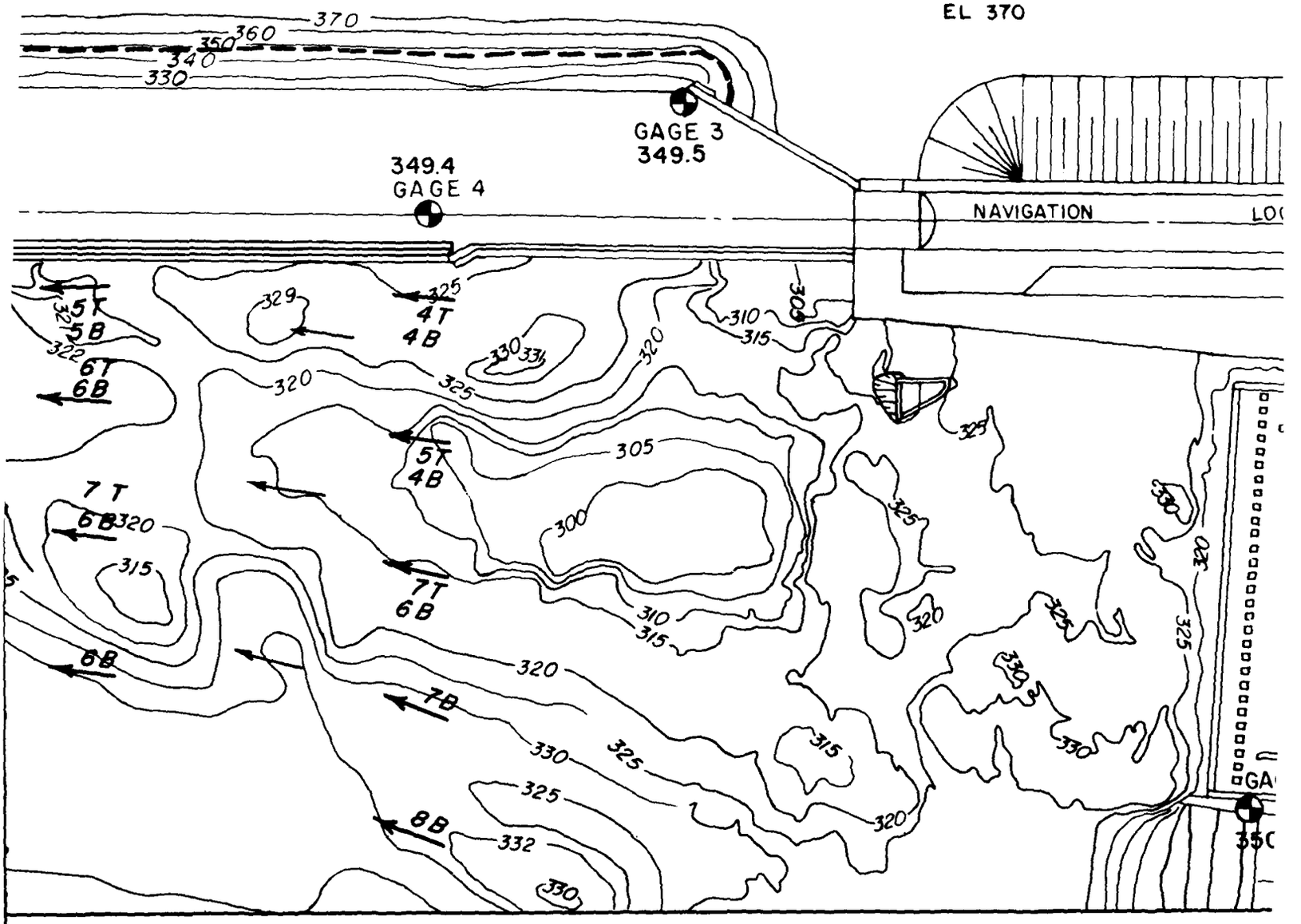
SPILLWAY BAYS 1 TO

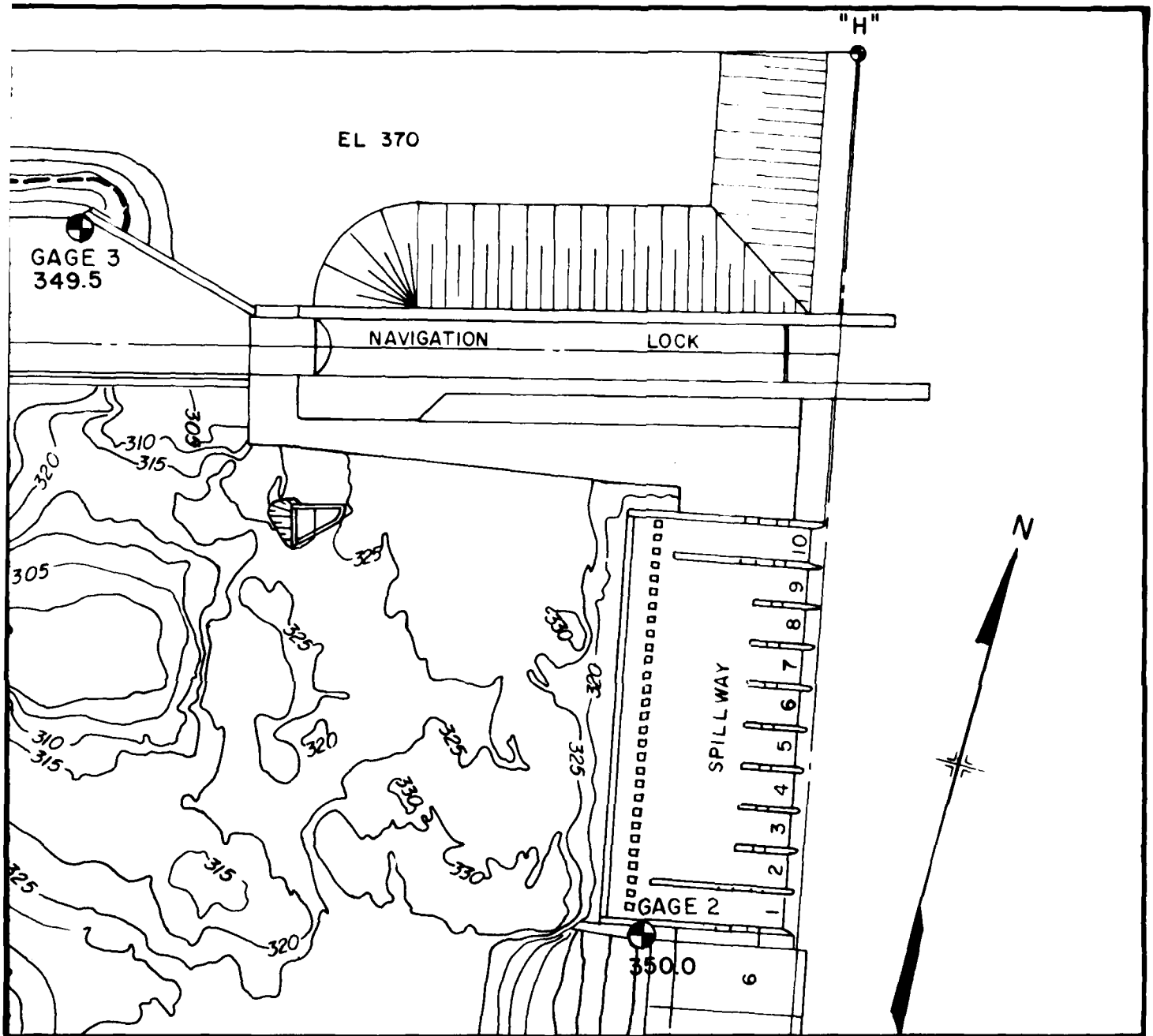
POWERHOUSE UNITS

POWERHOUSE UNITS



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000	CFS
POWERHOUSE UNITS 1 TO 3	43 300	CFS
POWERHOUSE UNITS 4 TO 6	56 700	CFS

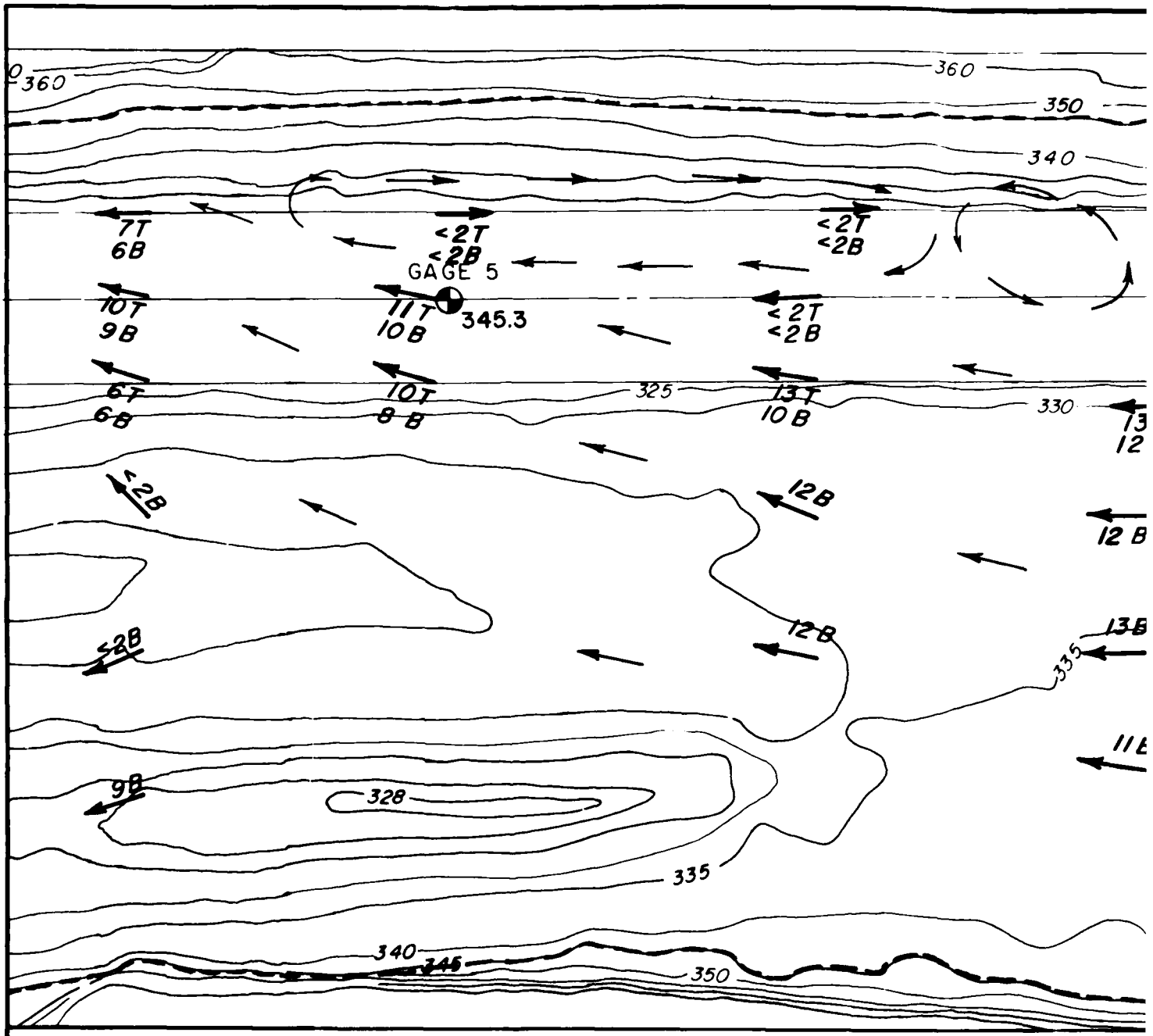


1000-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 13

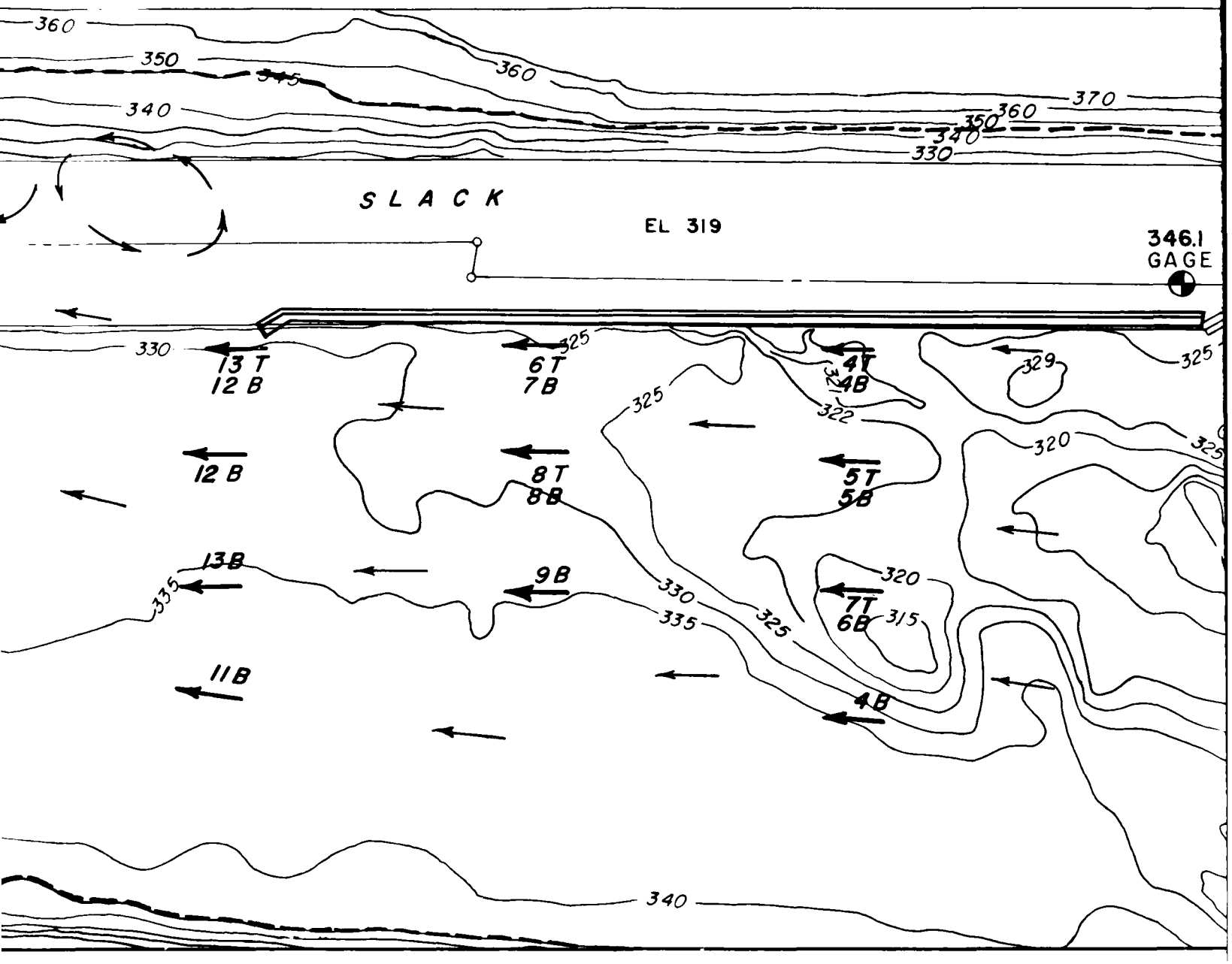


LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



SCALE

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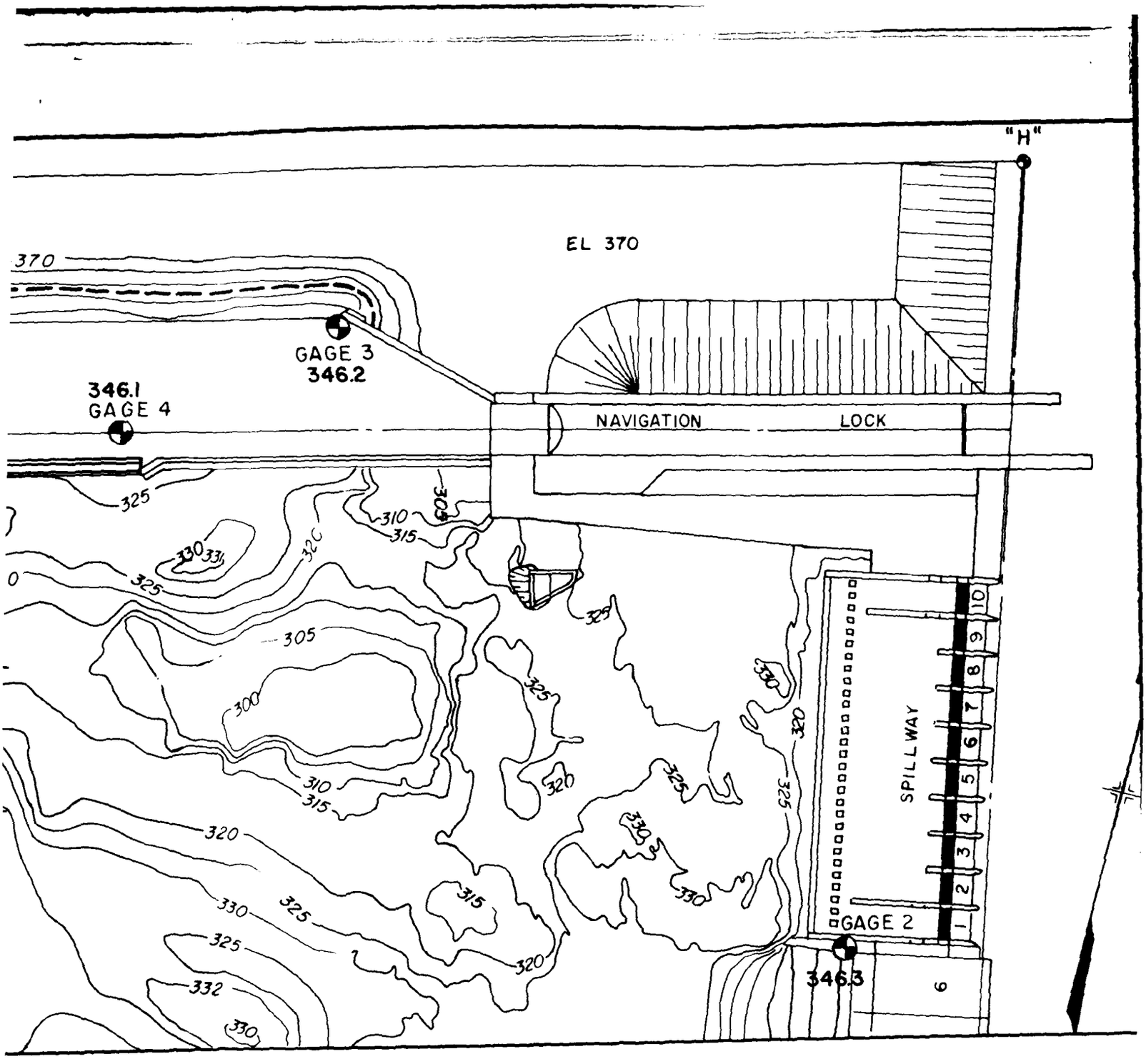
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



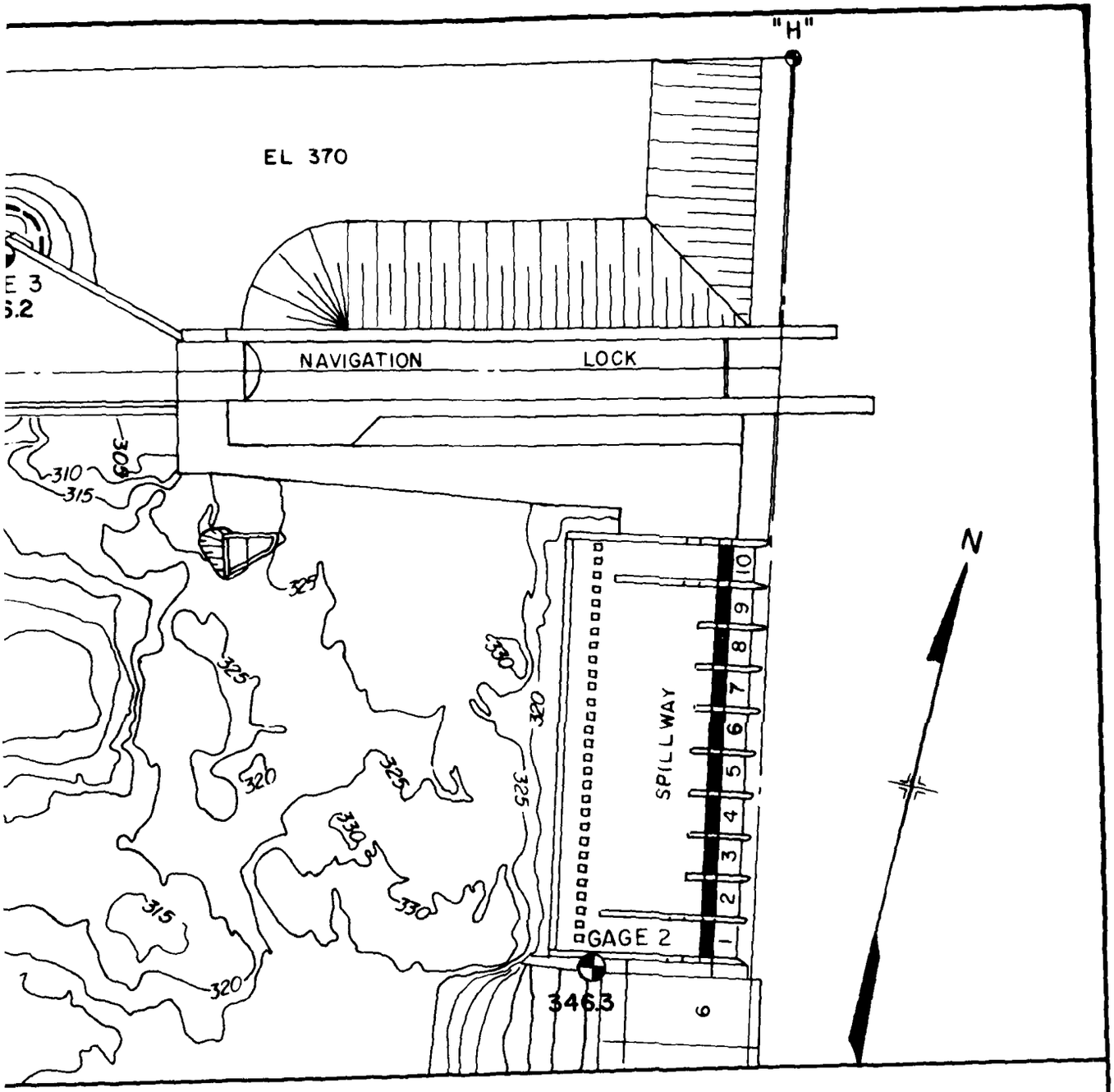
1500-FT WALL EXT

W DISTRIBUTION

TO 10	CLOSED
S 1 TO 3	43 300 CFS
S 4 TO 8	56 700 CFS

FLOW CONDITIO

RIVER DISCHARGE 100(
McNARY POOL EL

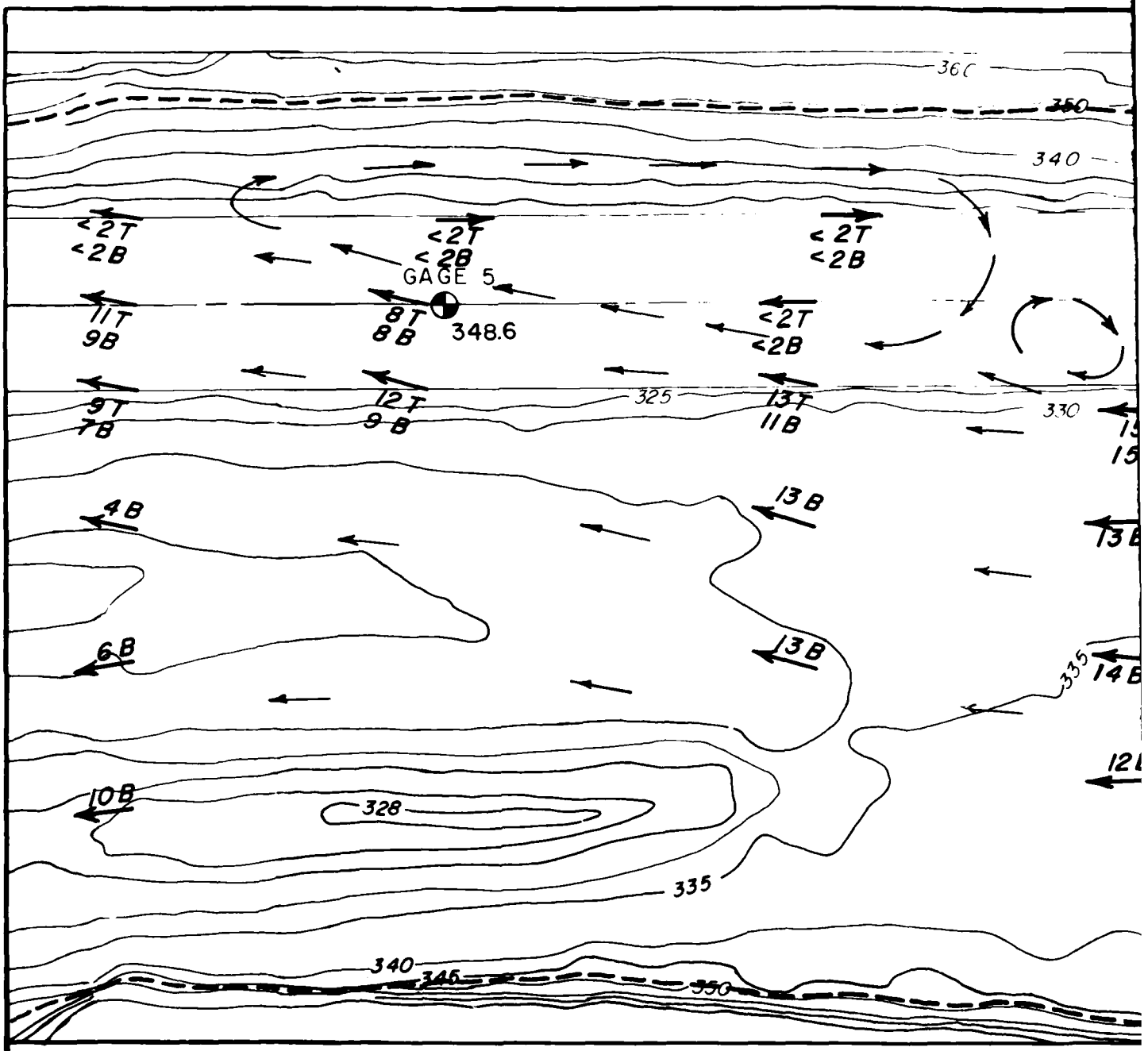


1500-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 14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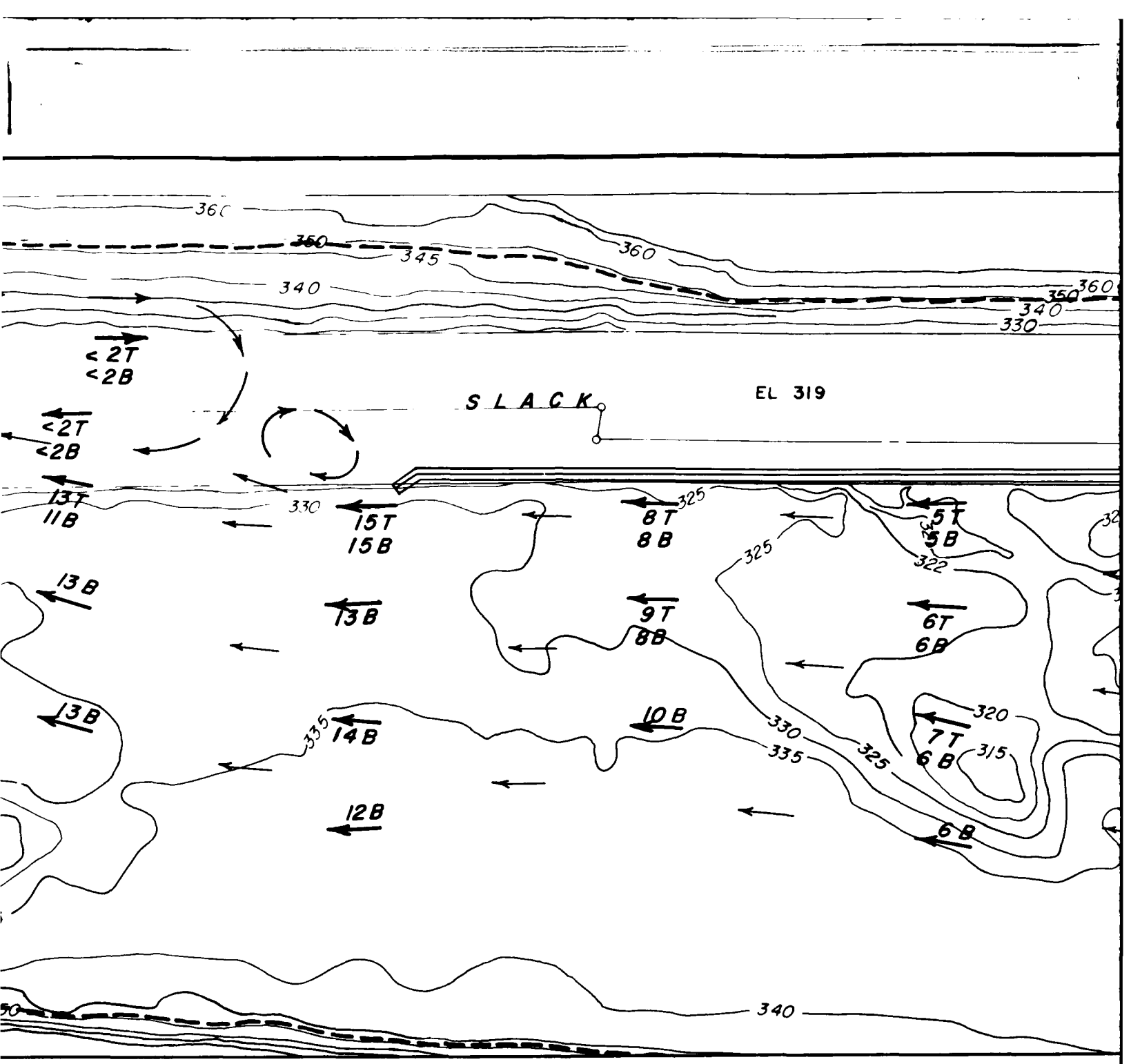
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



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ND

ES IN FPS

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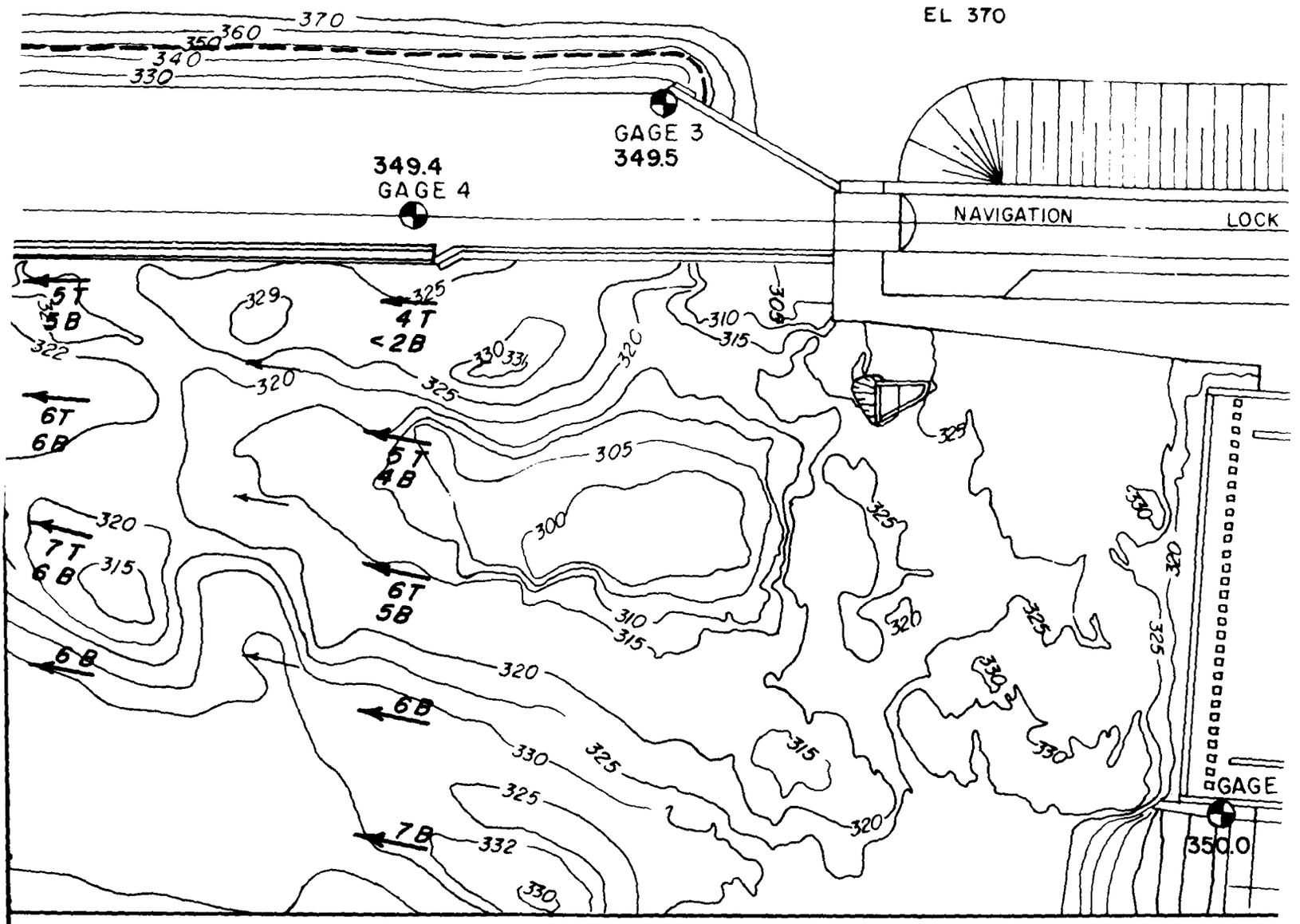
SPILLWAY BAYS 1

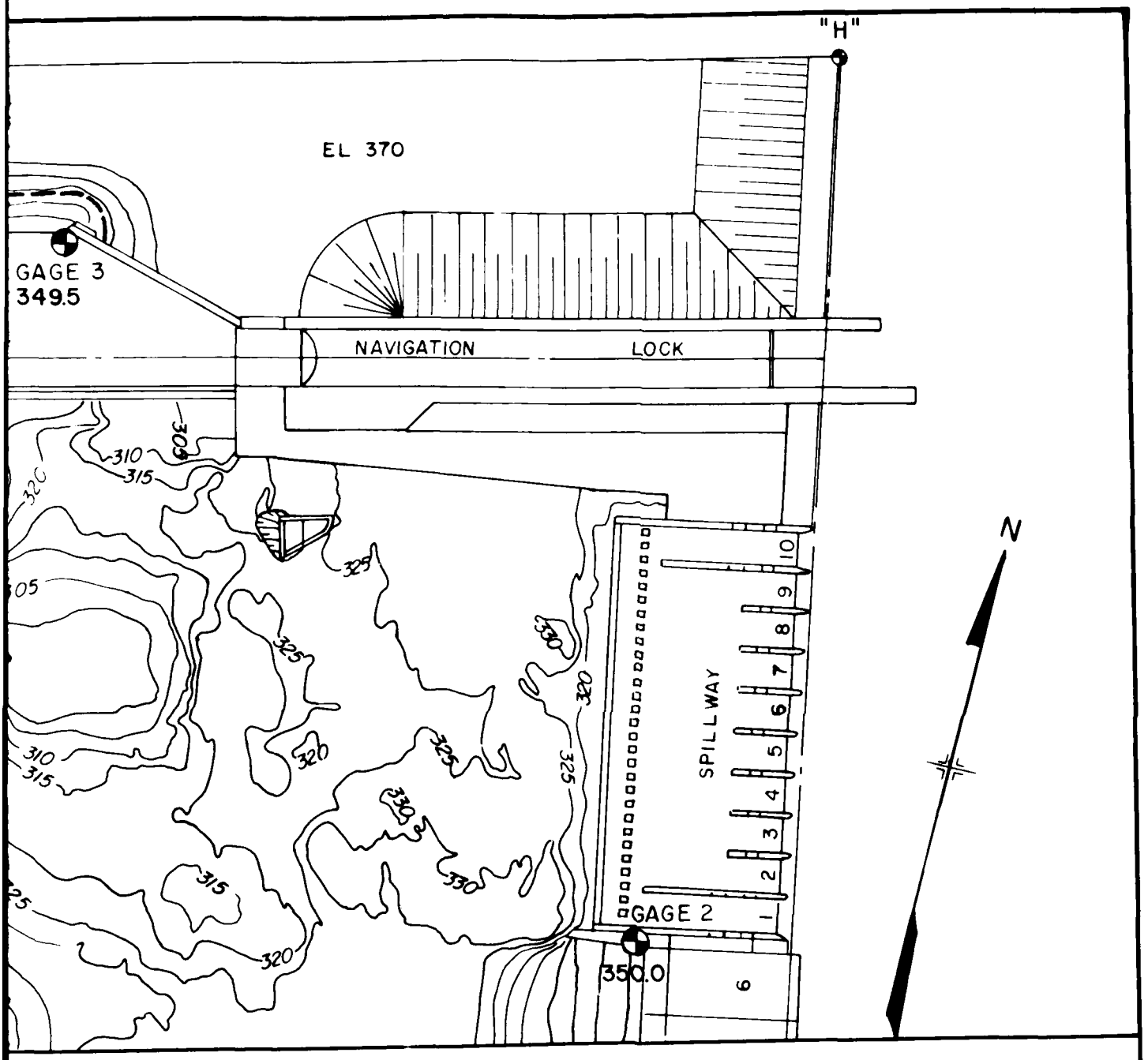
POWERHOUSE UNIT

POWERHOUSE UNIT



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000	CFS
POWERHOUSE UNITS 1 TO 3	43 000	CFS
POWERHOUSE UNITS 4 TO 6	56 700	CFS

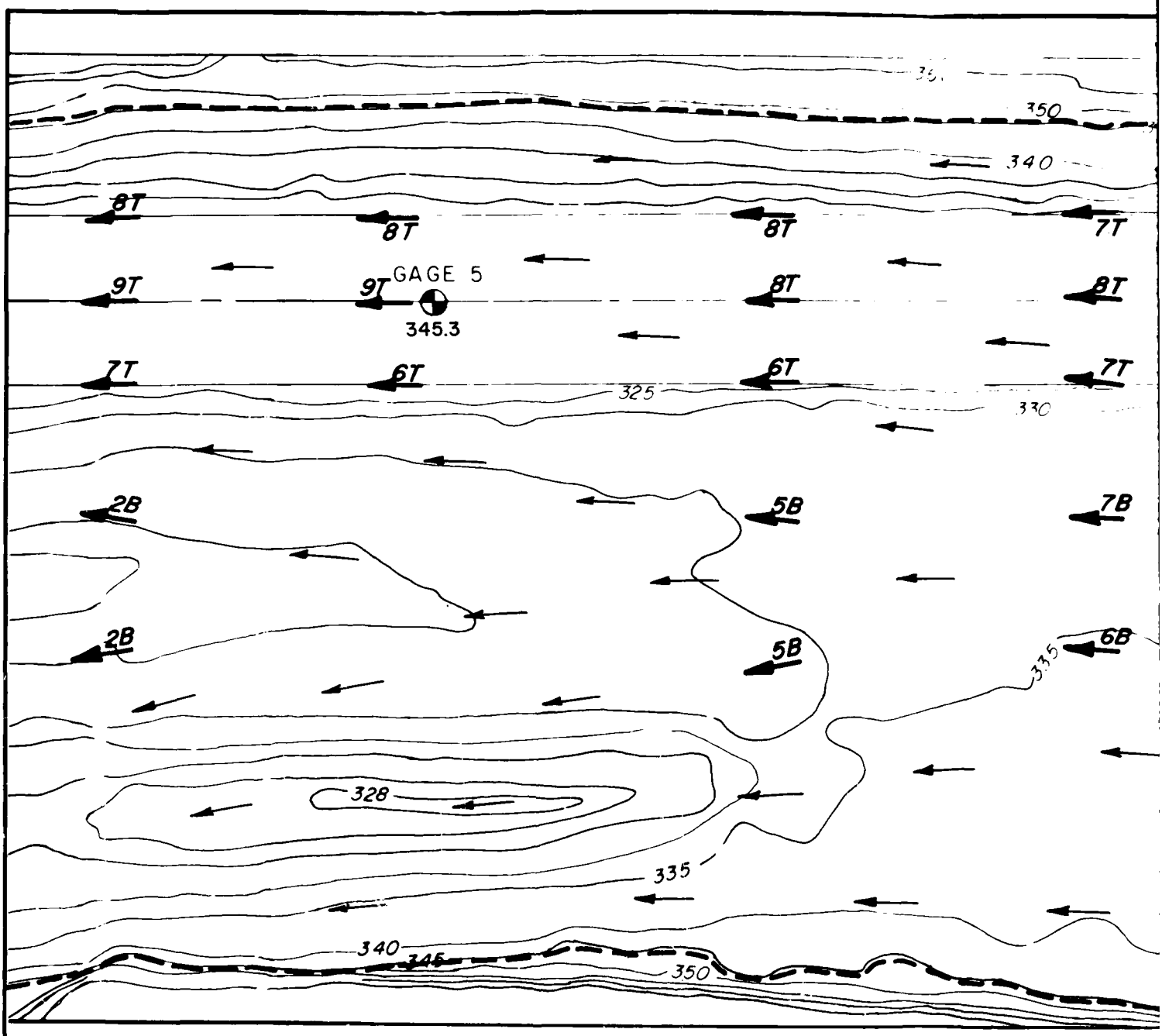


1500-FT WALL EXTENSION

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 15



LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM

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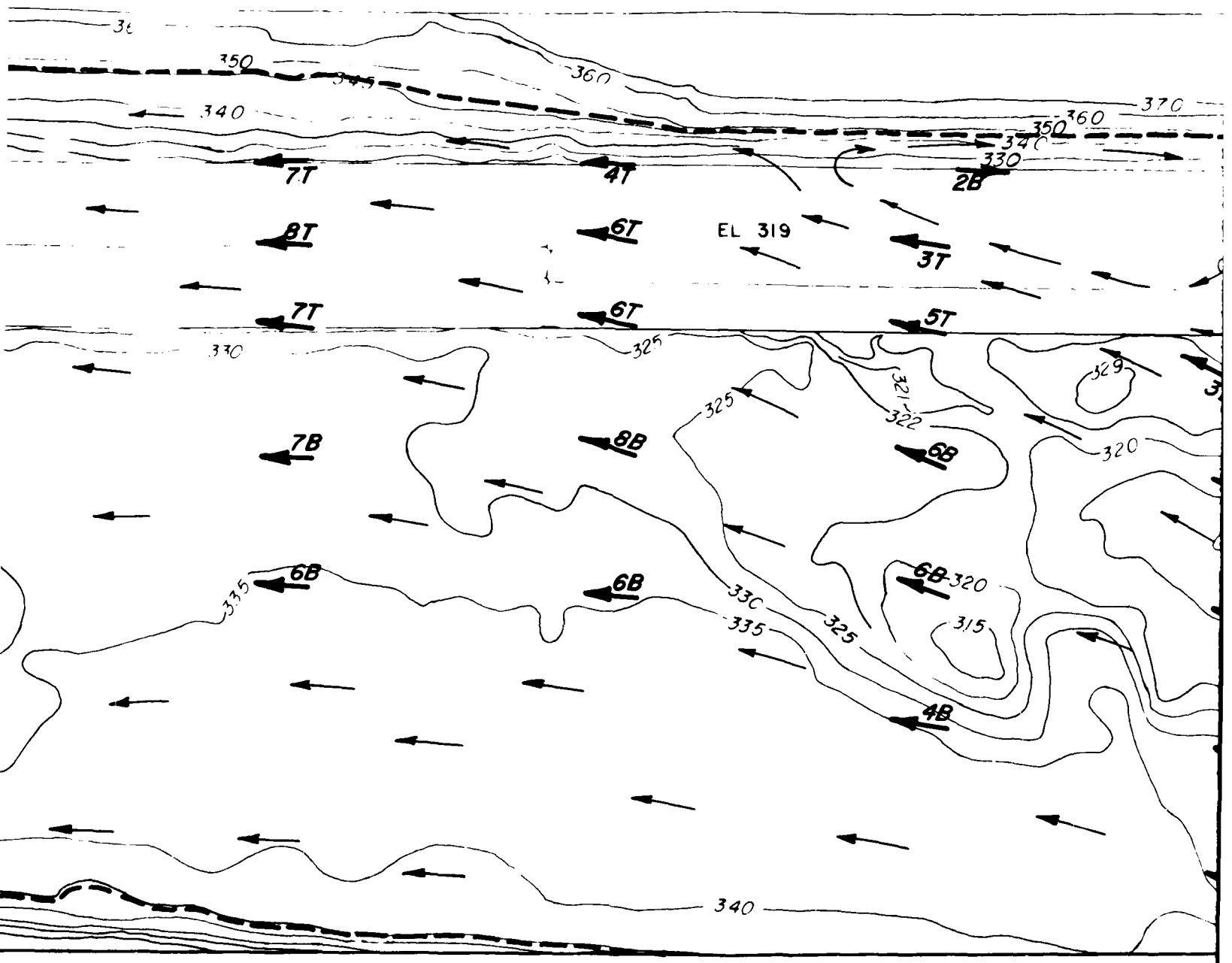

SCALE

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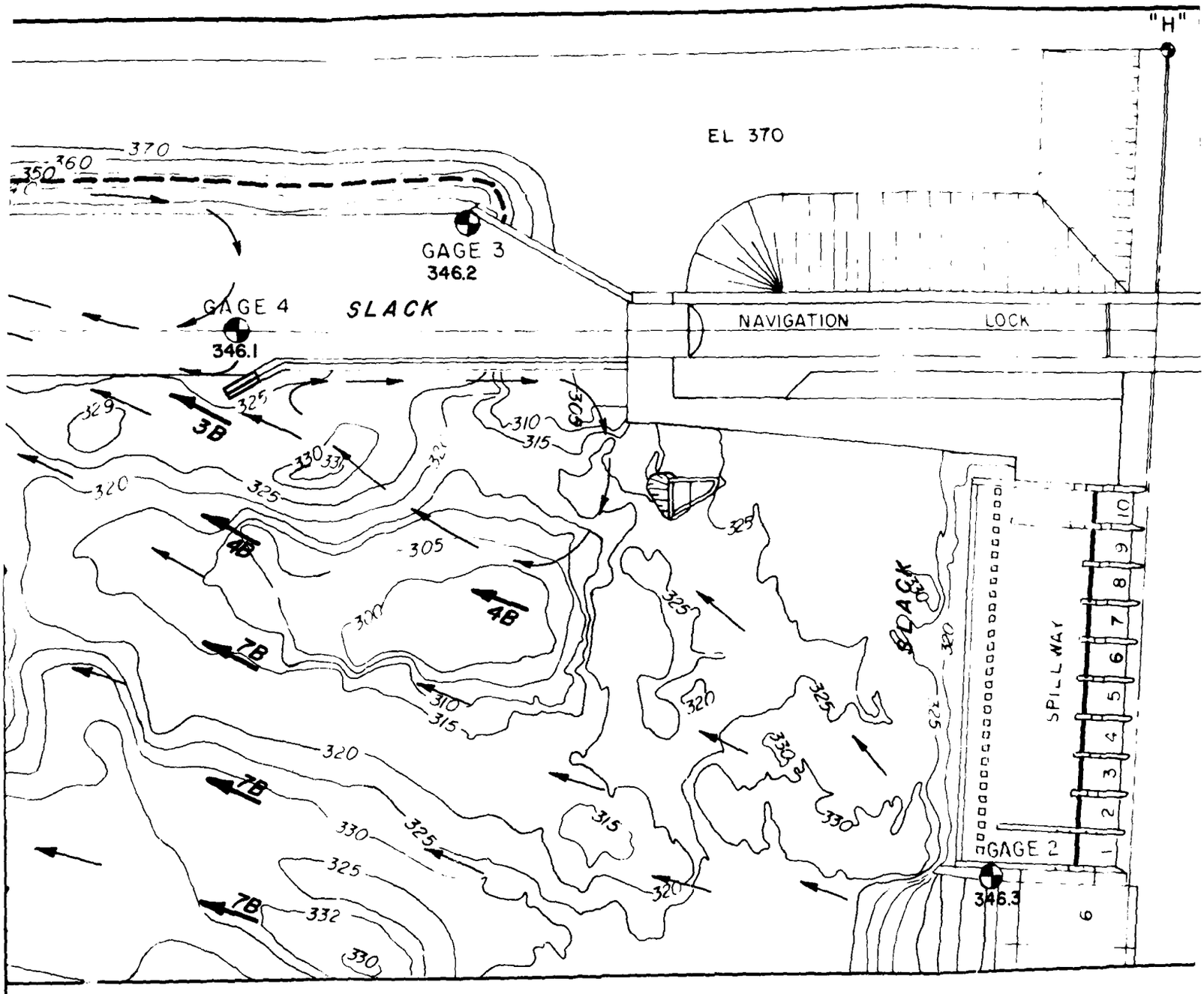
FLOW DISTRI

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

Y BAYS 1 TO 10	CLOSED
OUSE UNITS 1 TO 3	43 300 CFS
OUSE UNITS 4 TO 6	56 700 CFS

70-FT EXTENSI

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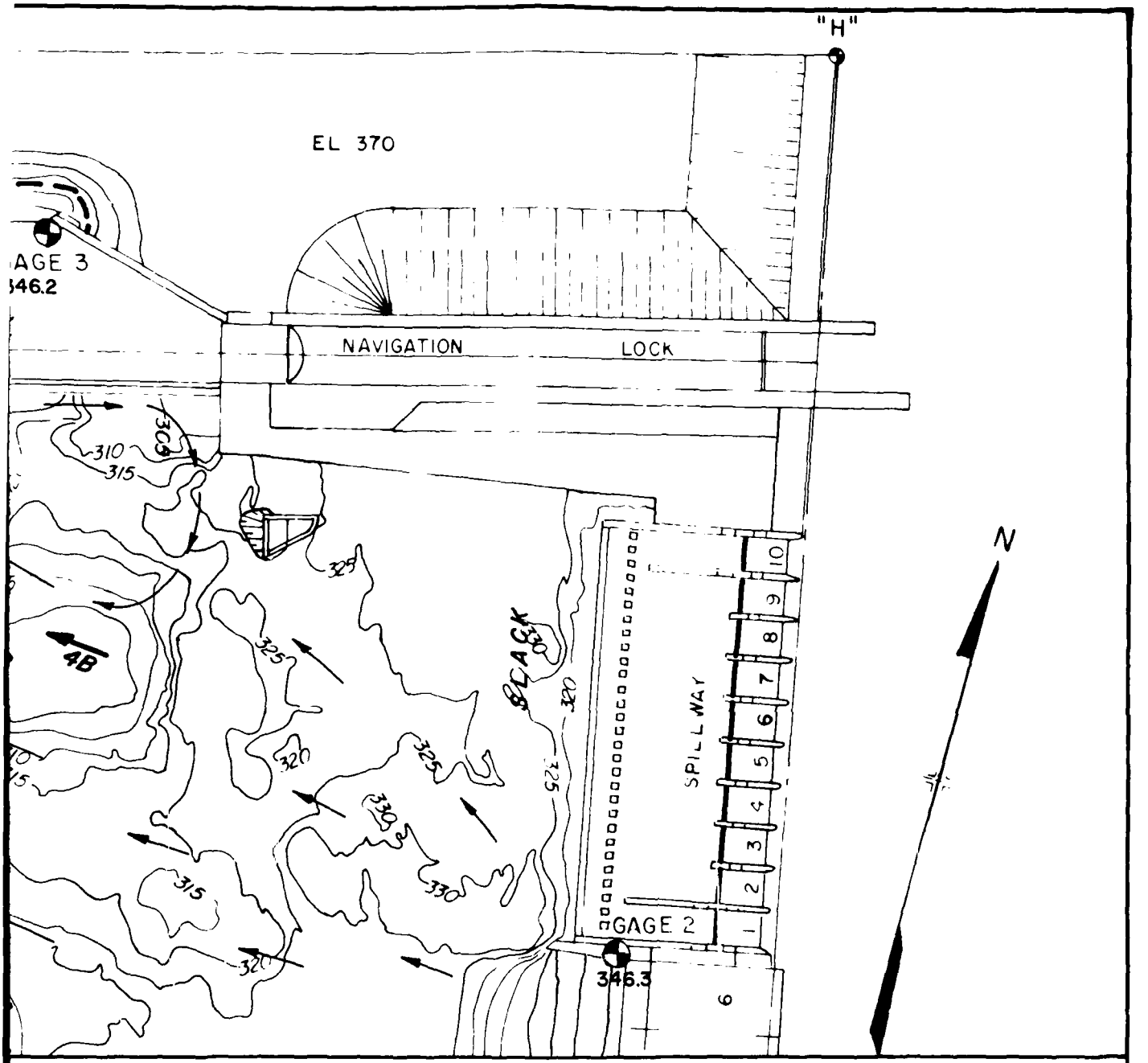
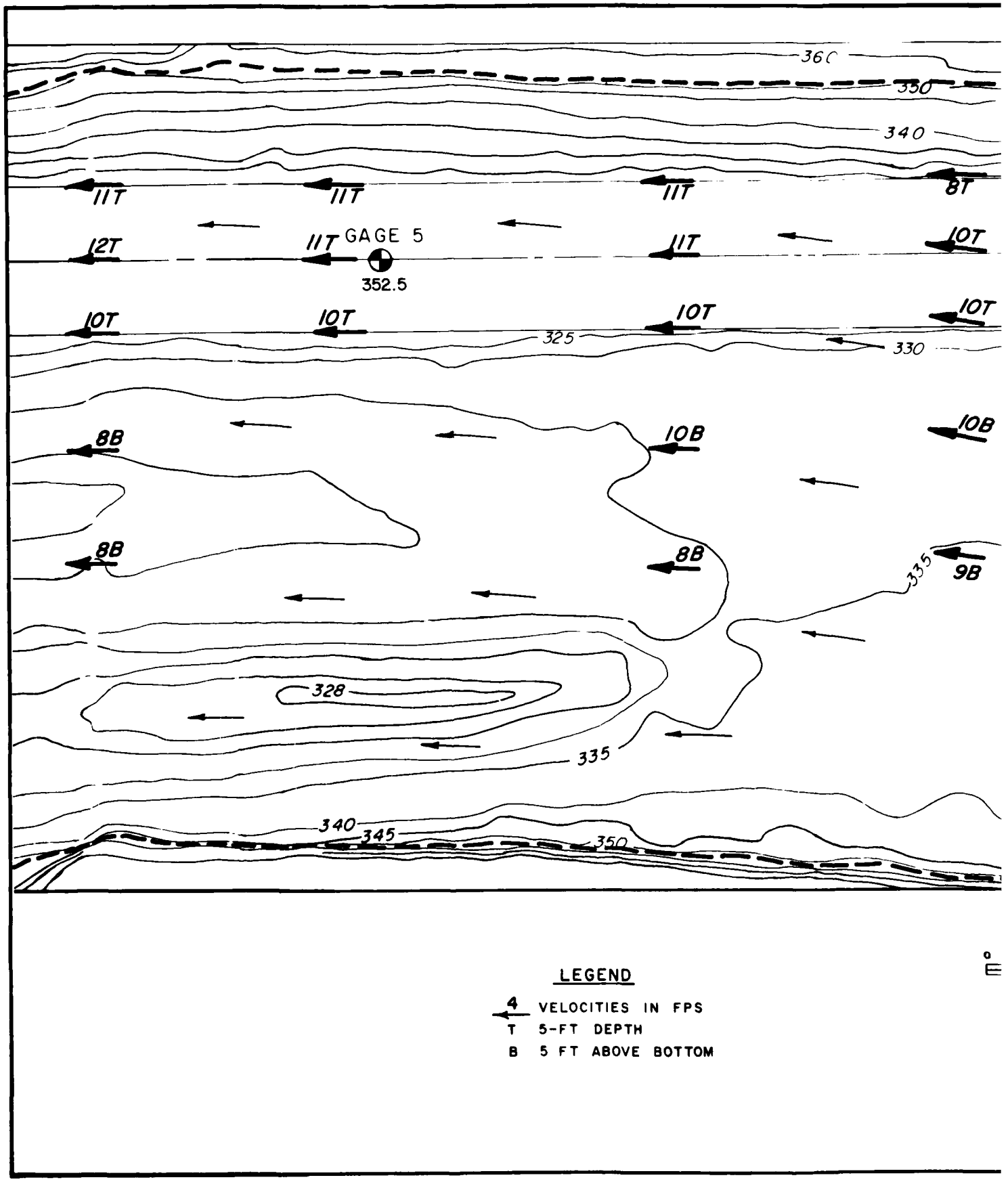


70-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 16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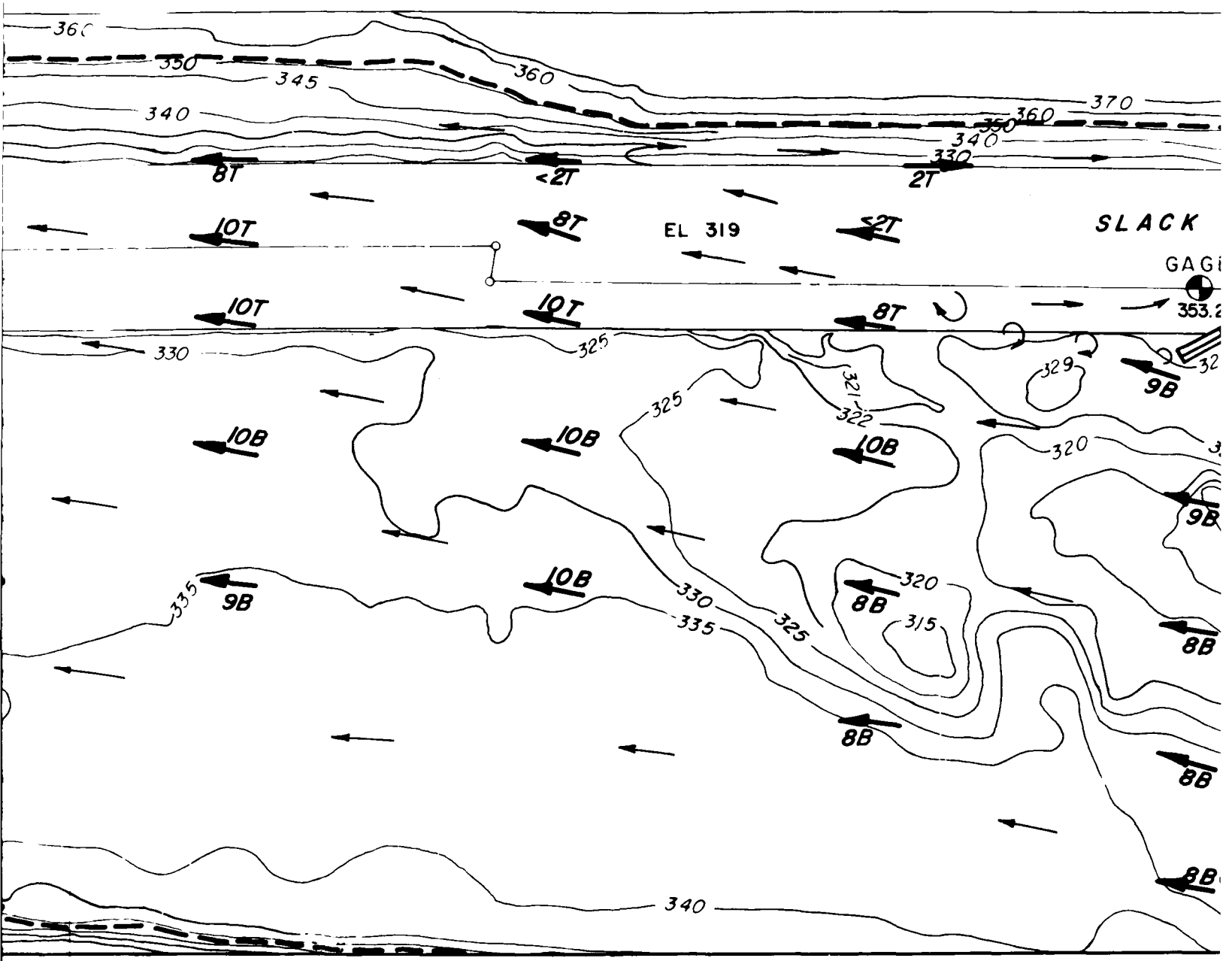
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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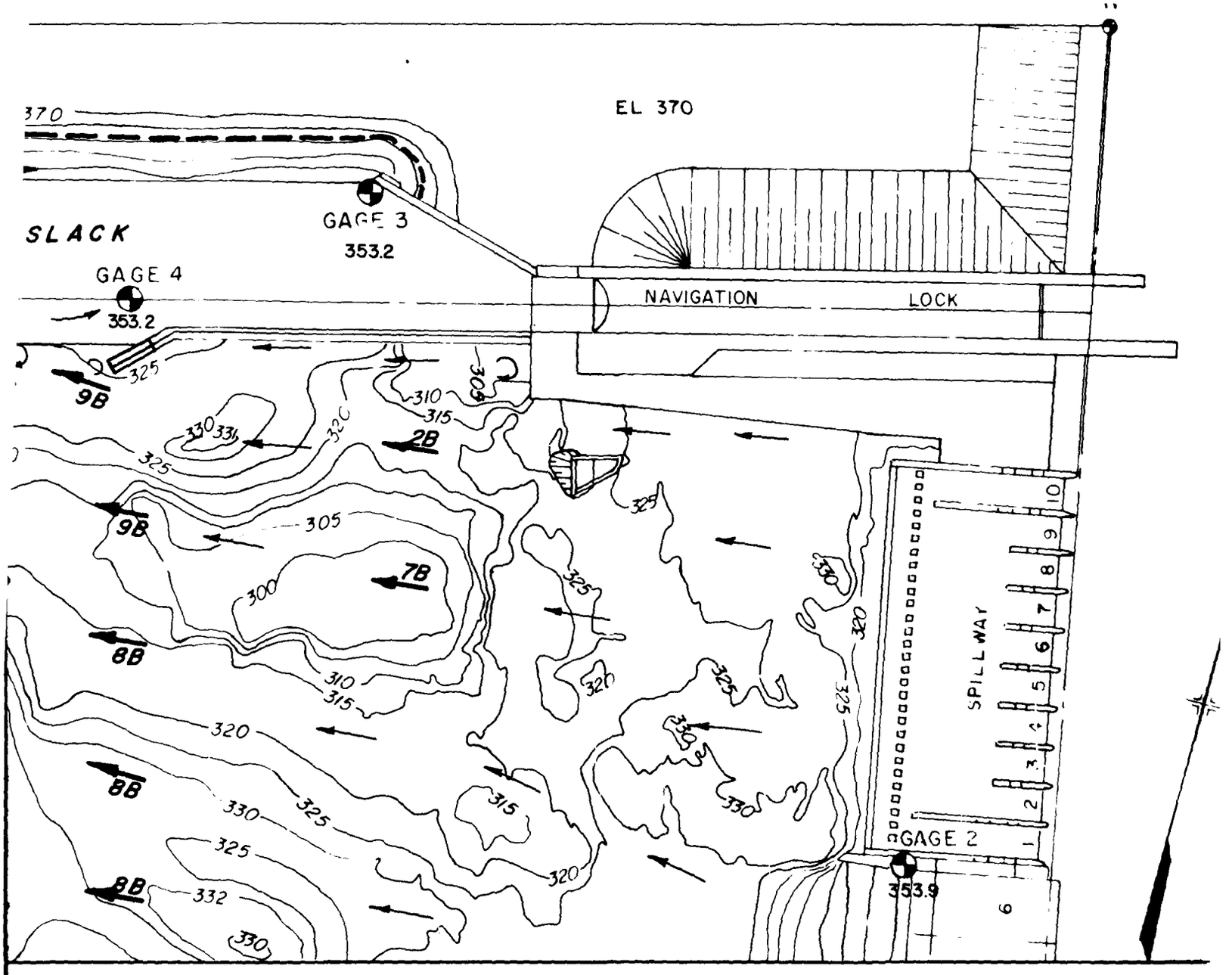
FLOW DISTRIBUTIO

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



DISTRIBUTION

10	119 200	CFS
1 TO 3	45 300	CFS
4 TO 6	55 500	CFS

70-FT EXTENSION TO GUI

FLOW CO

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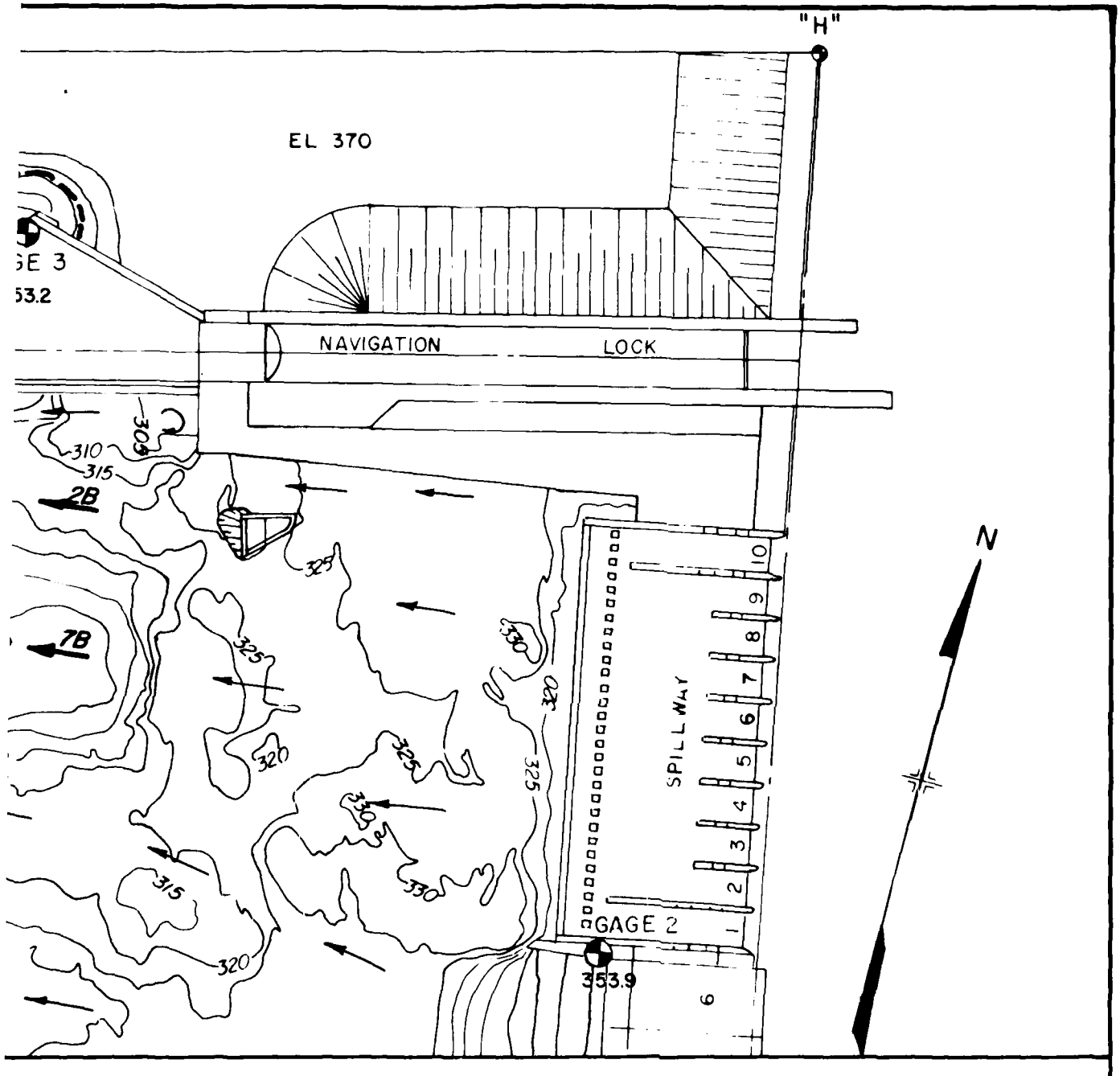
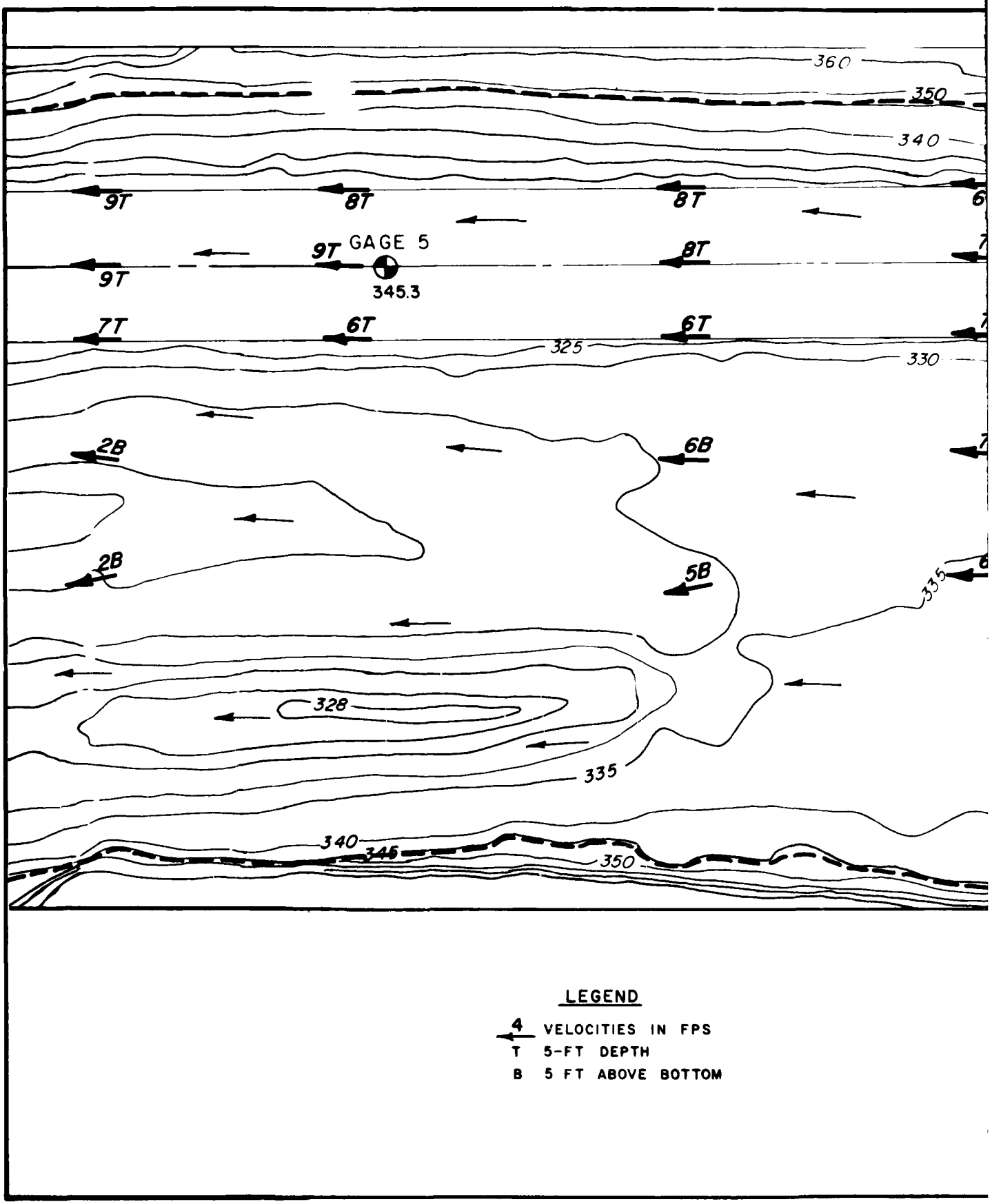


70-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 220 000 CFS
McNARY POOL EL 335

PLATE 17

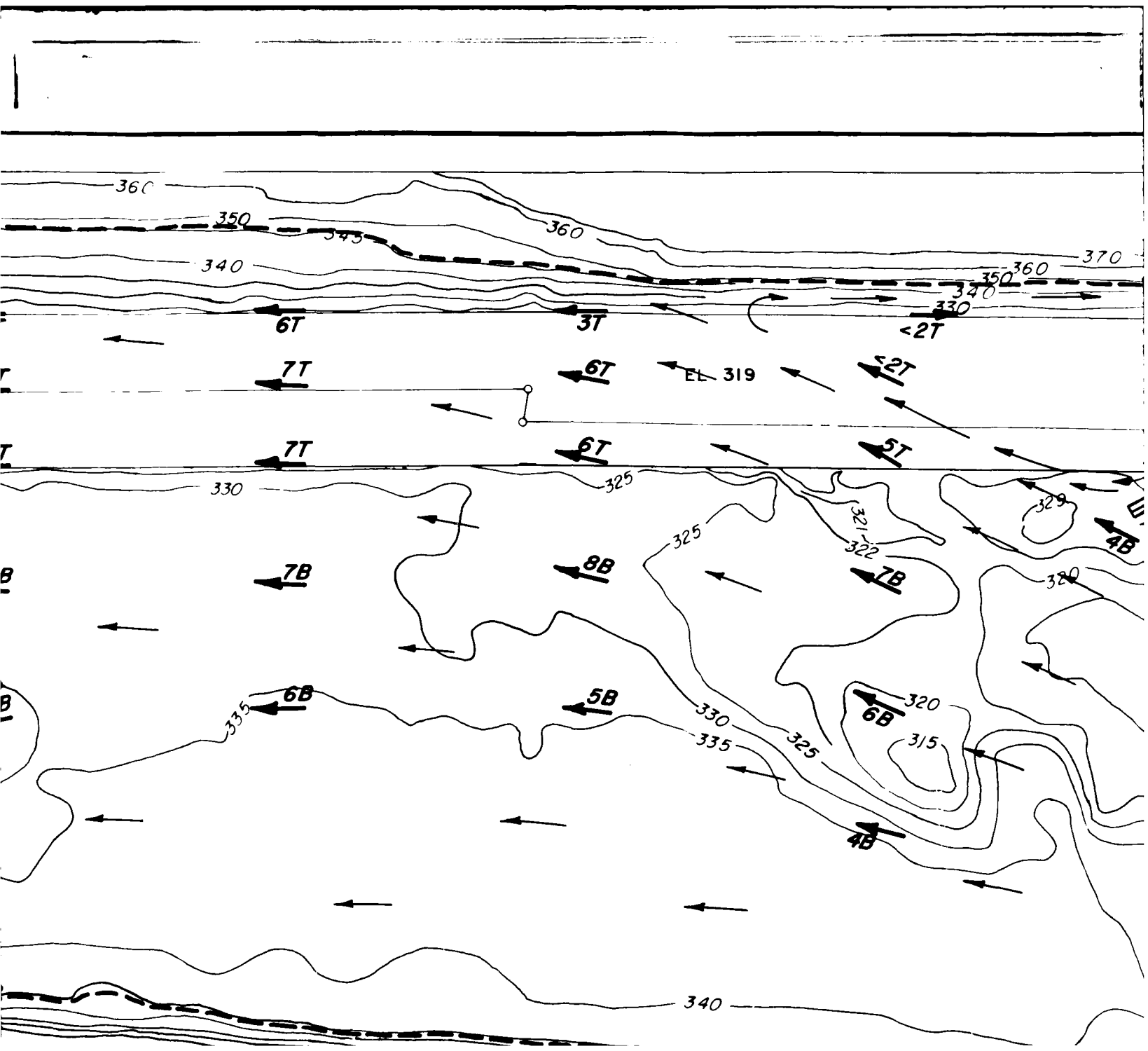


LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM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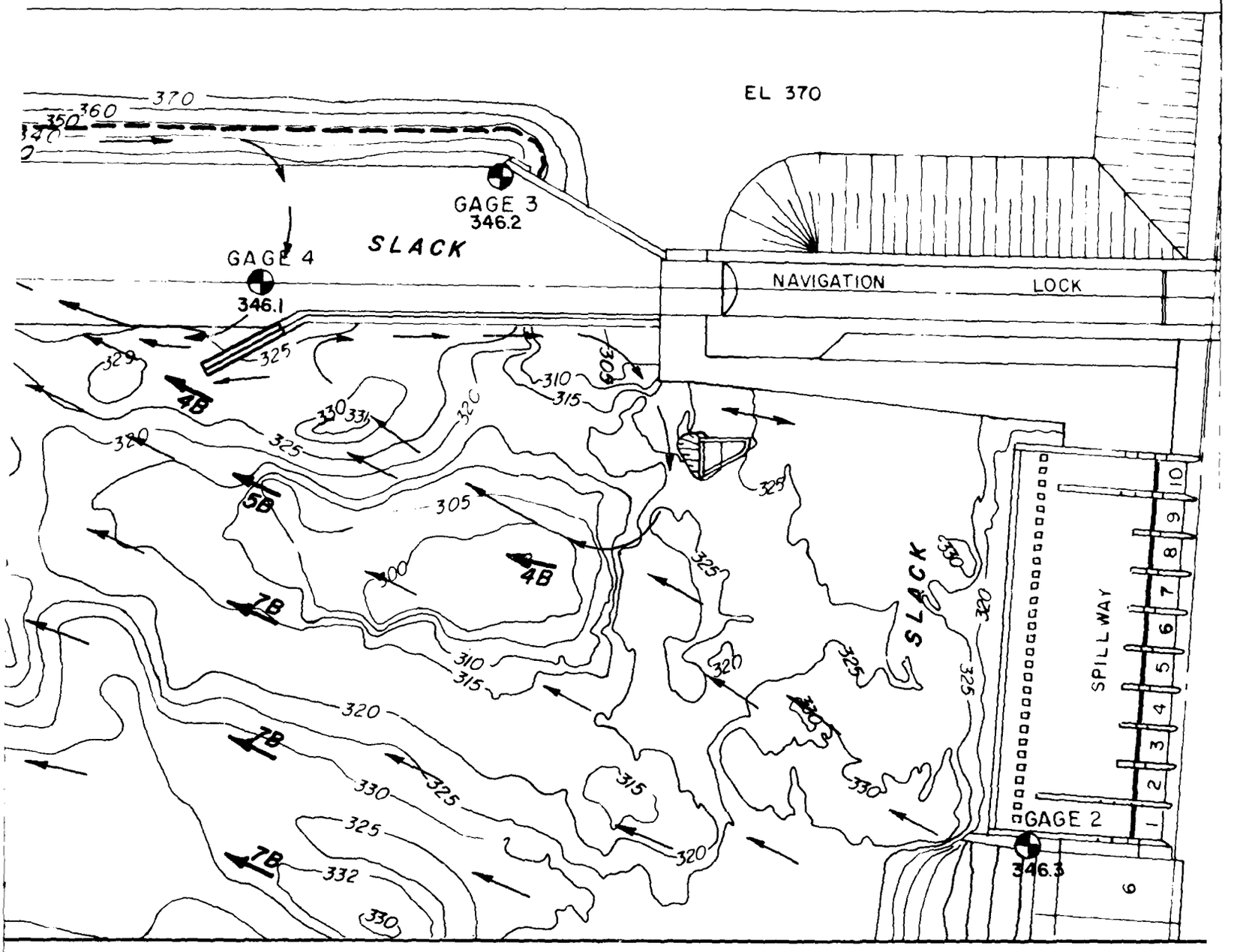

FLOW DISTRIBUTION

WAY BAYS 1 TO 10	CLOSED
RHOUSE UNITS 1 TO 3	43 300 CFS
RHOUSE UNITS 4 TO 6	56 700 CFS

140-FT EXTEN

FLOW

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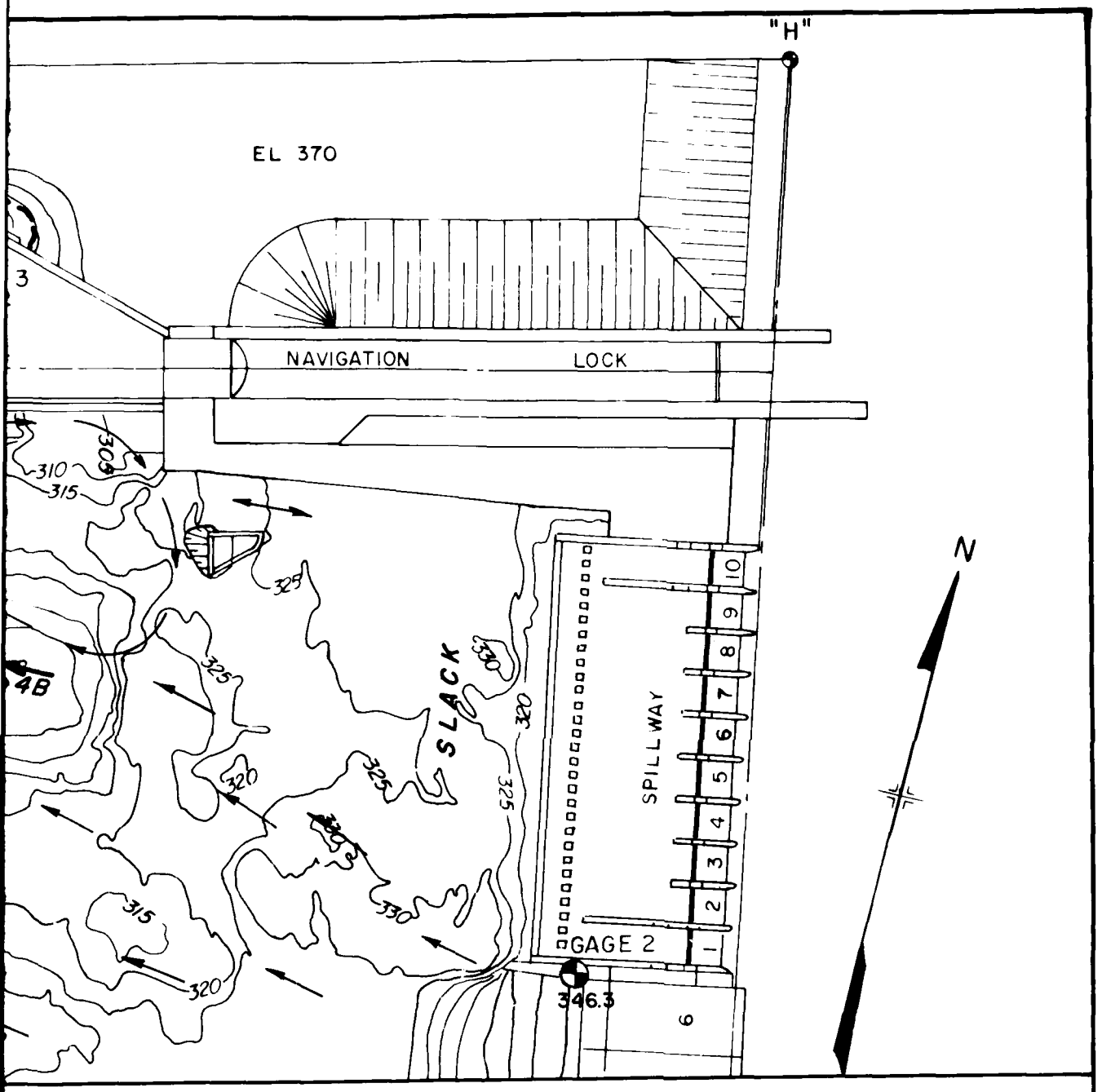
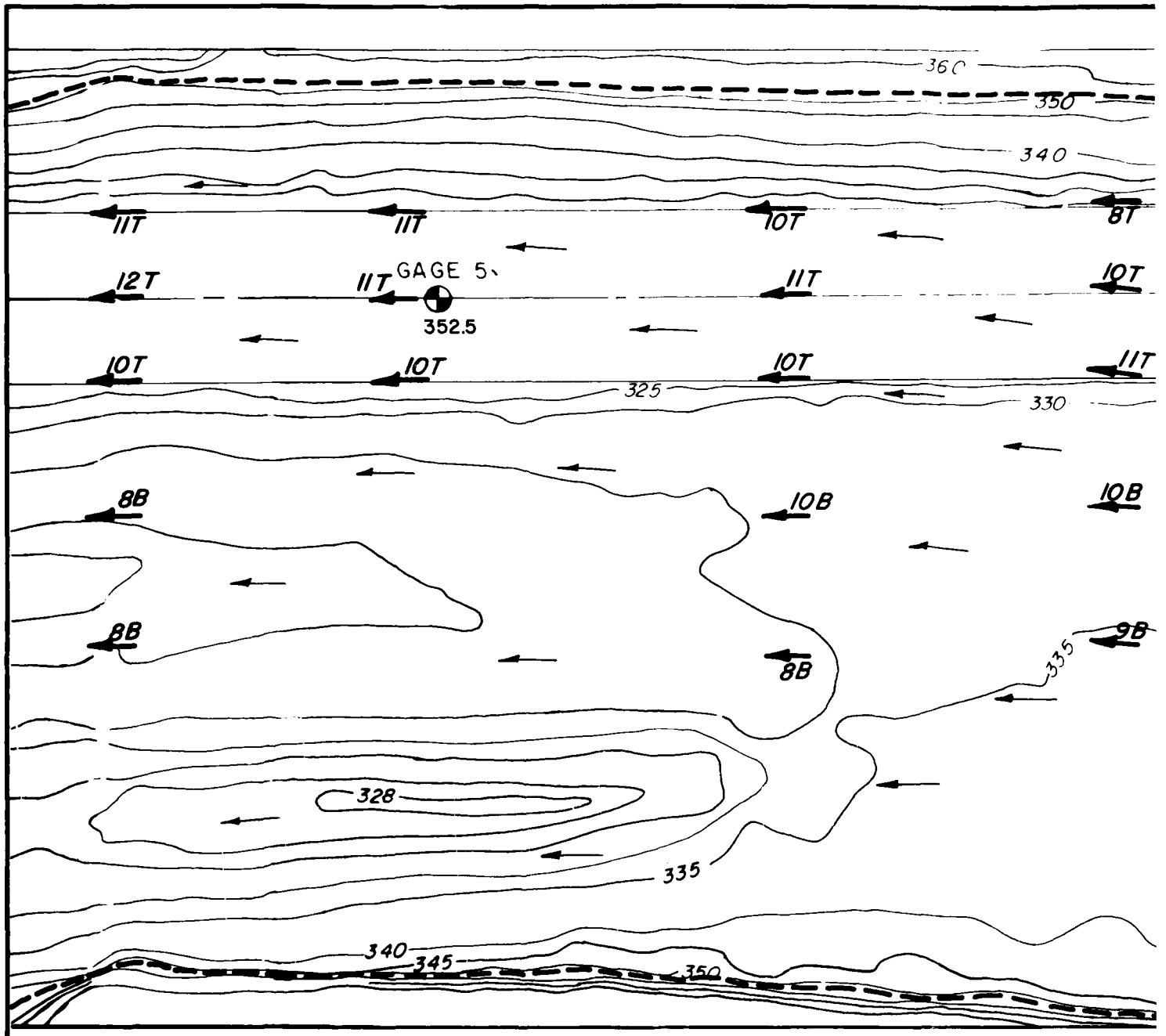


140-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 18

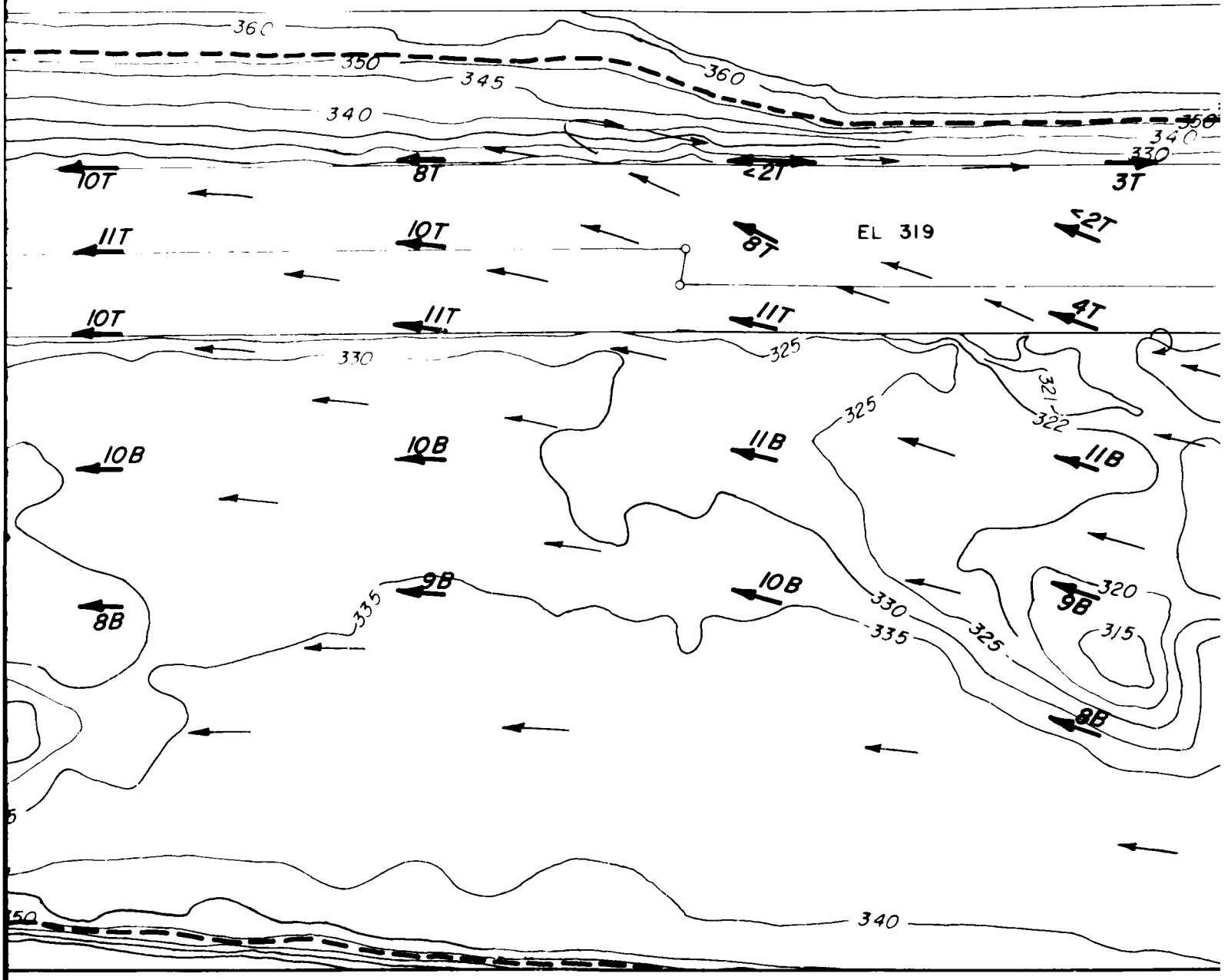


LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



SCALE

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IES IN FPS

EPTH

BOVE BOTTOM

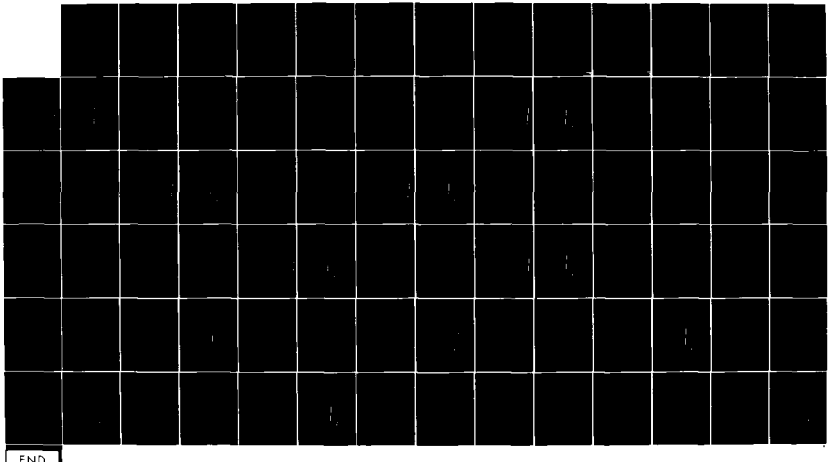
SPILLWAY BAYS

POWERHOUSE

POWERHOUSE

AD-A134 686 MCNARY RESERVOIR NAVIGATION AT ICE HARBOR DAM SNAKE RIVER WASHINGTON HYDR..(U) ARMY ENGINEER DIV NORTH PACIFIC BONNEVILLE OR DIV HYDRAULIC L.. AUG 83 2/2

UNCLASSIFIED TR-192-1 F/G 13/2 NL



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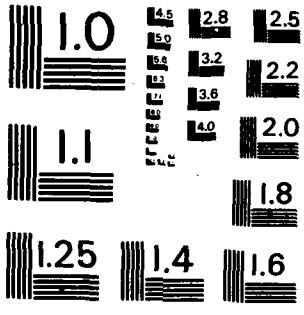

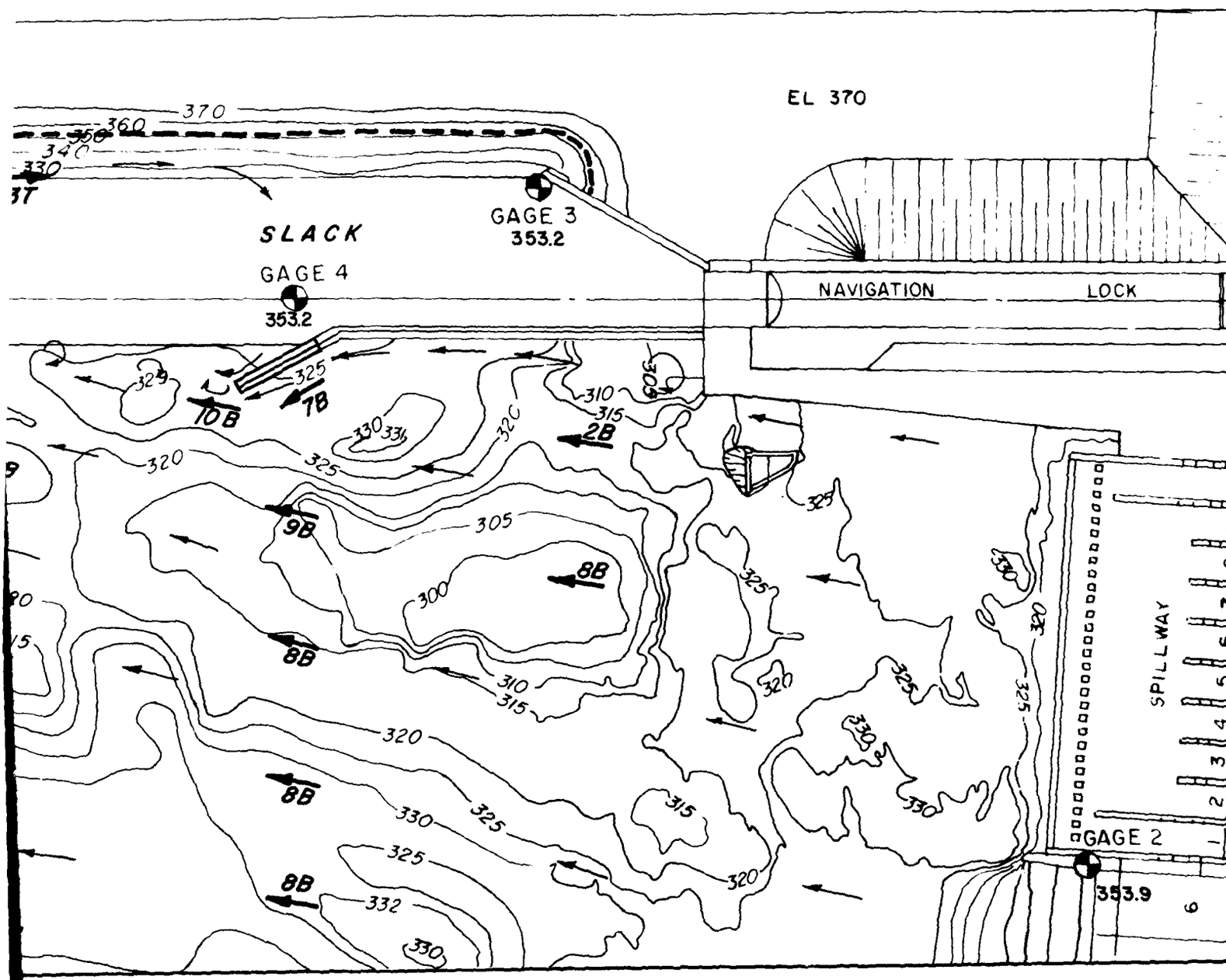

FLOW DISTRIBUTION

LWAY BAYS 1 TO 10	119 200 CFS
ERHOUSE UNITS 1 TO 3	45 300 CFS
ERHOUSE UNITS 4 TO 6	55 500 CFS

140-FT EX

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RIVER
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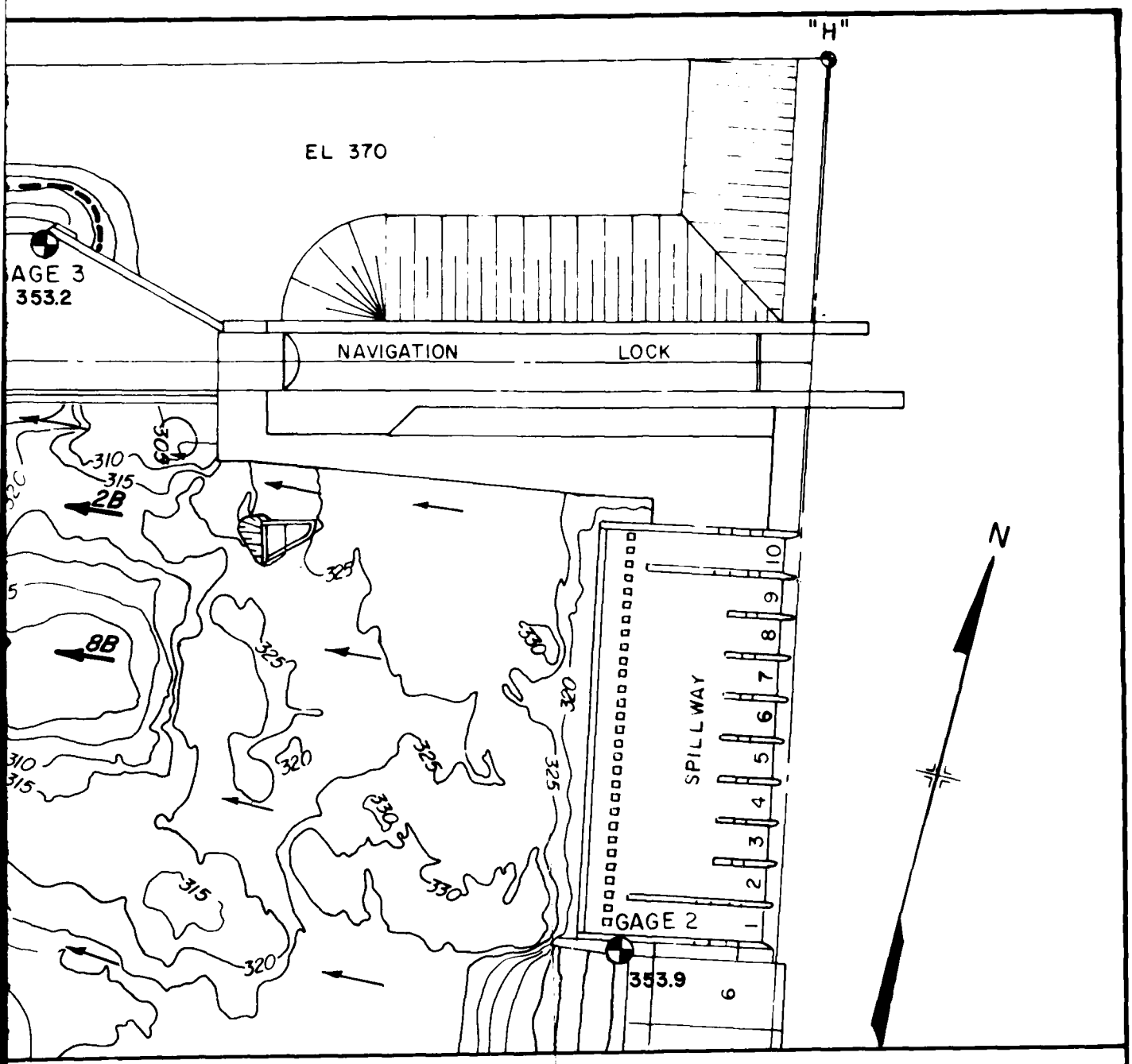


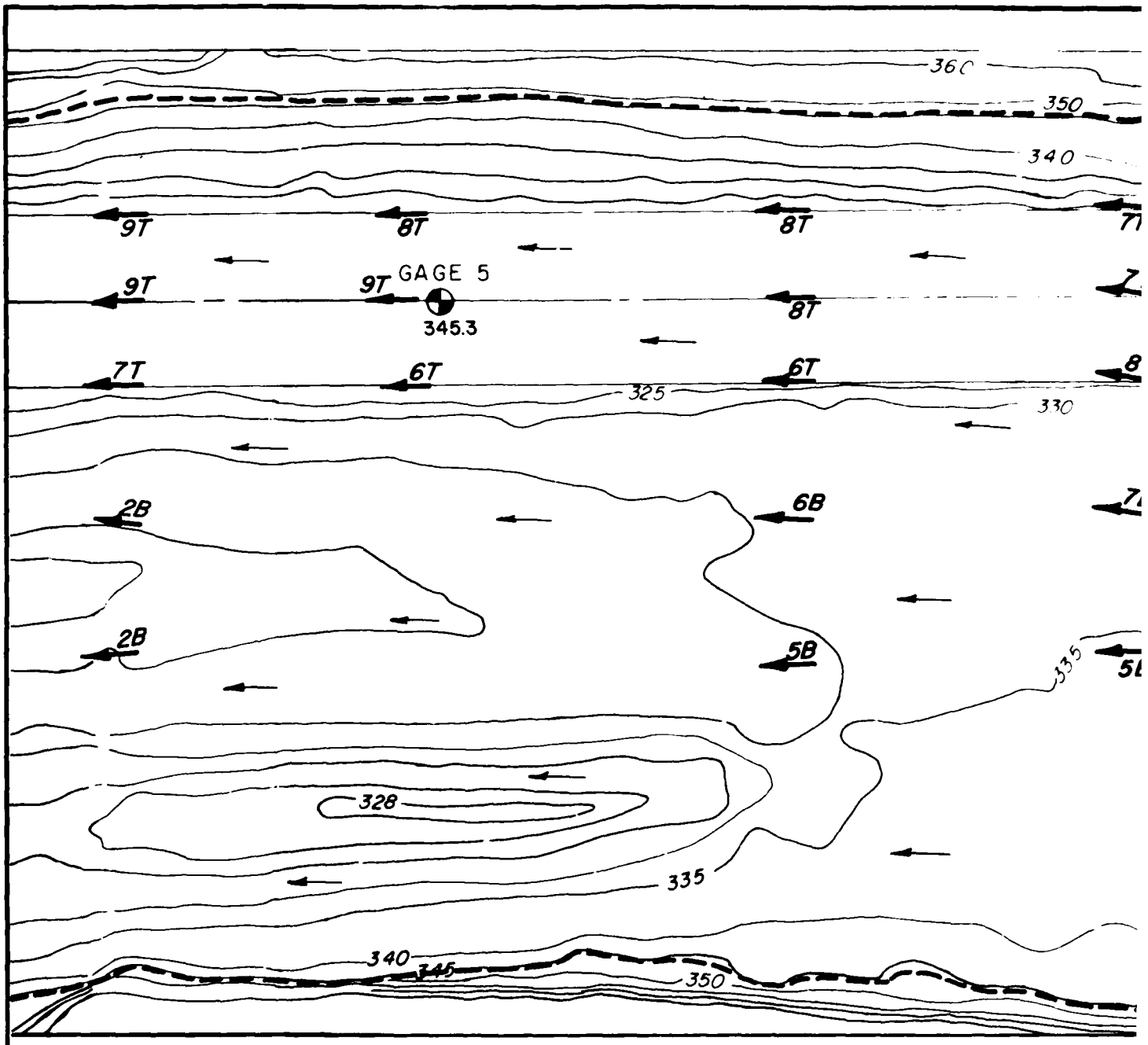
140-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 220 000 CFS
McNARY POOL EL 335

4

PLATE 19

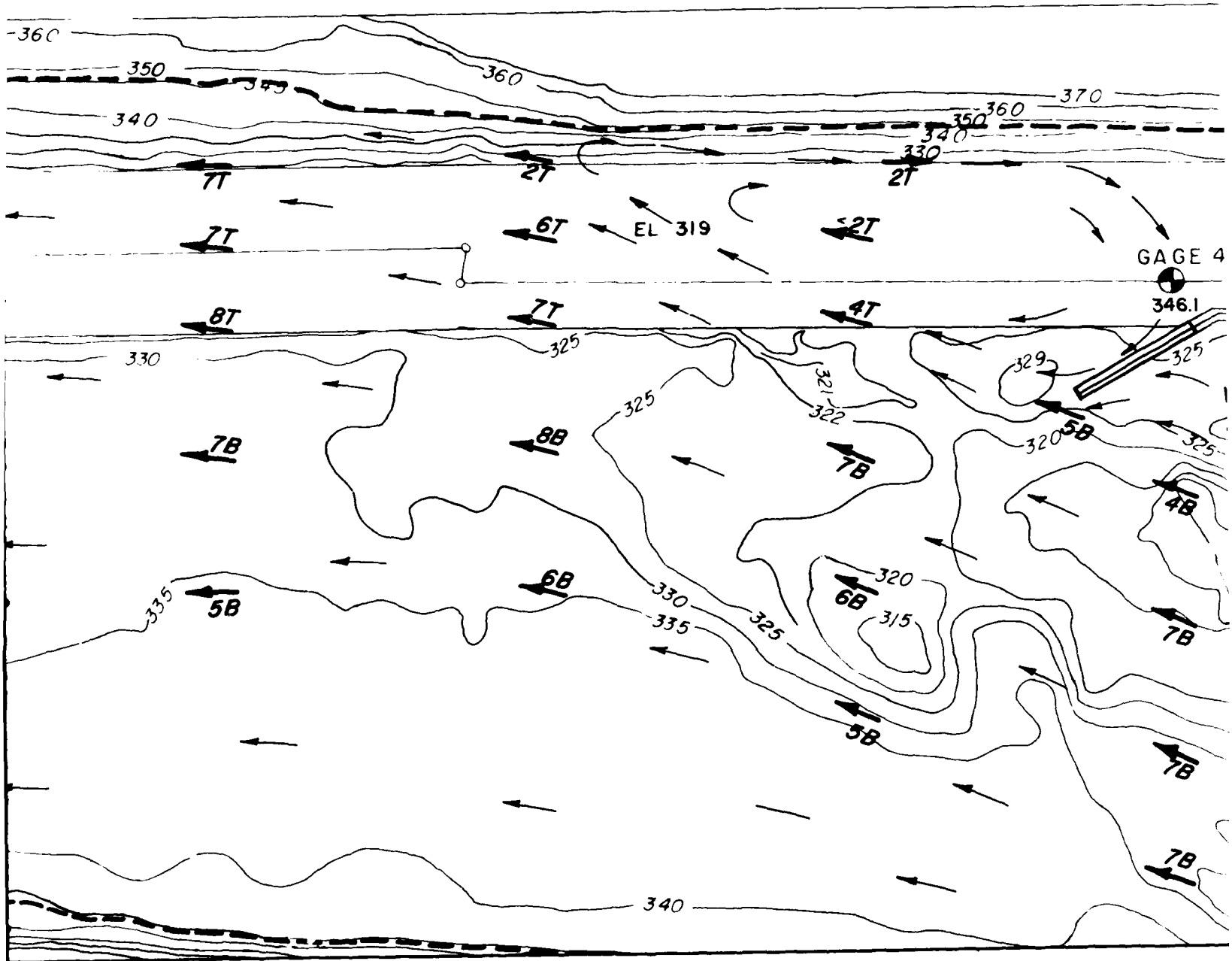


LEGEND

4 VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



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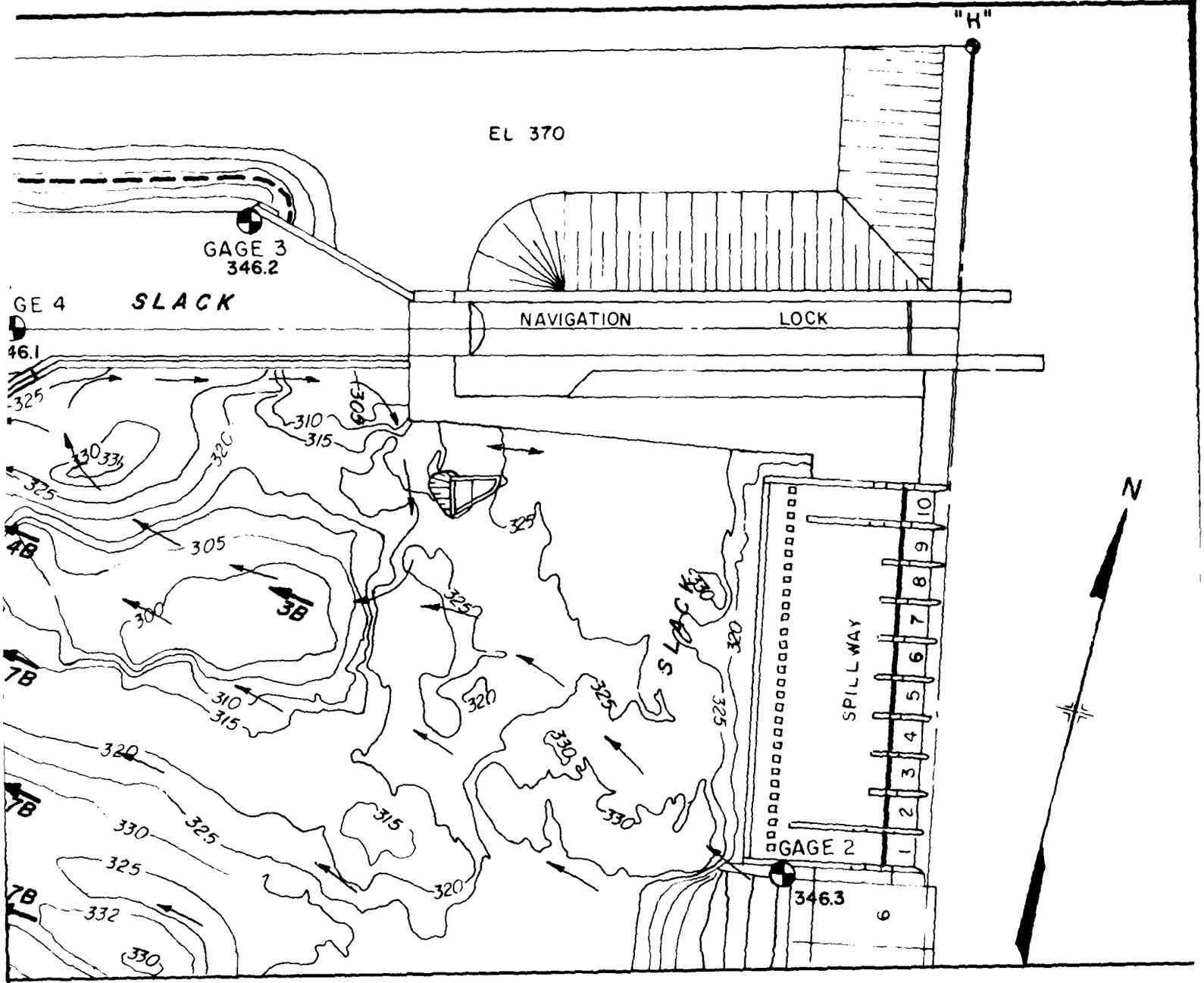
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



UTION

CLOSED

43 300 CFS

56 700 CFS

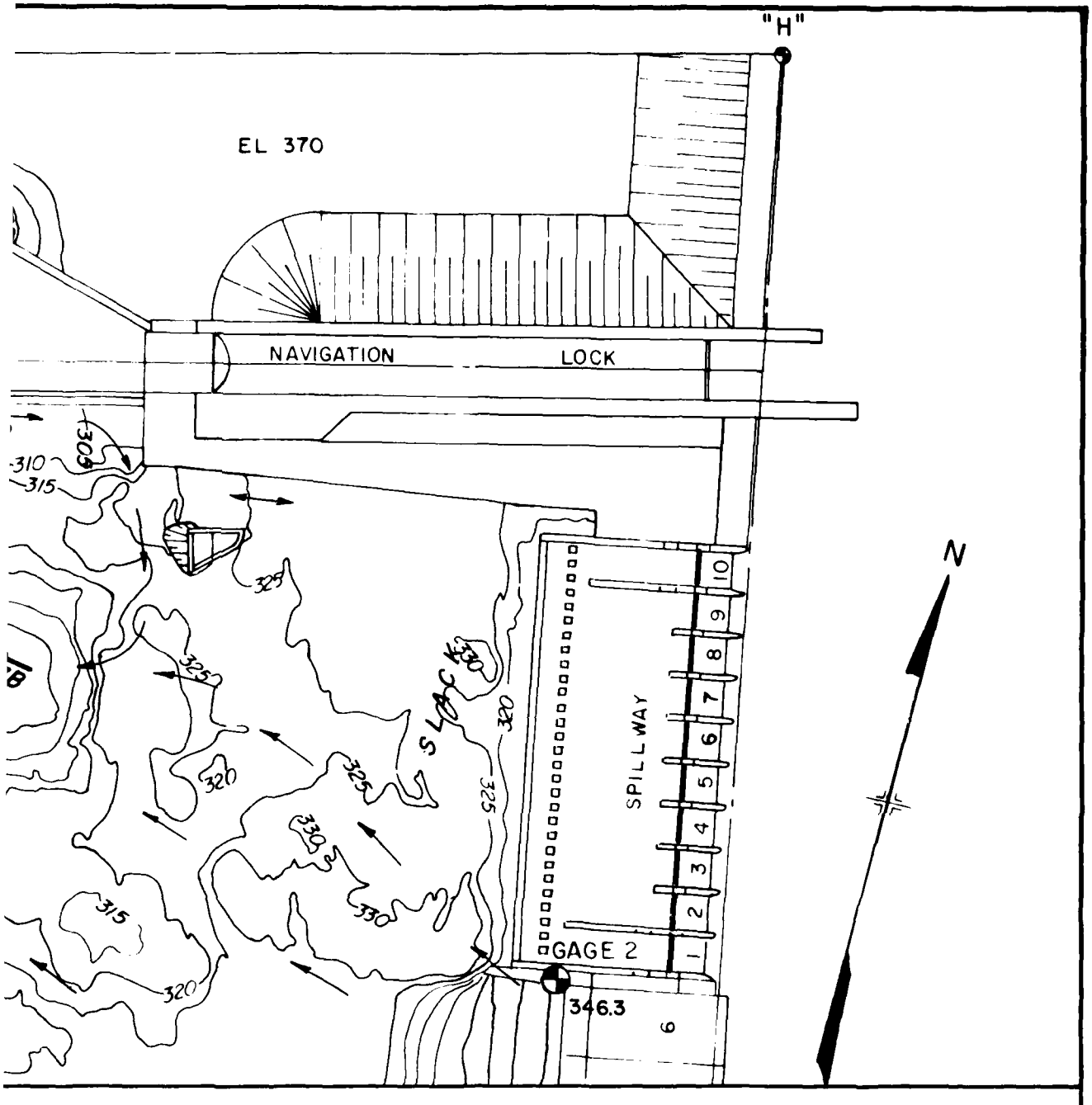
210-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS

McNARY POOL EL 335

PLAT

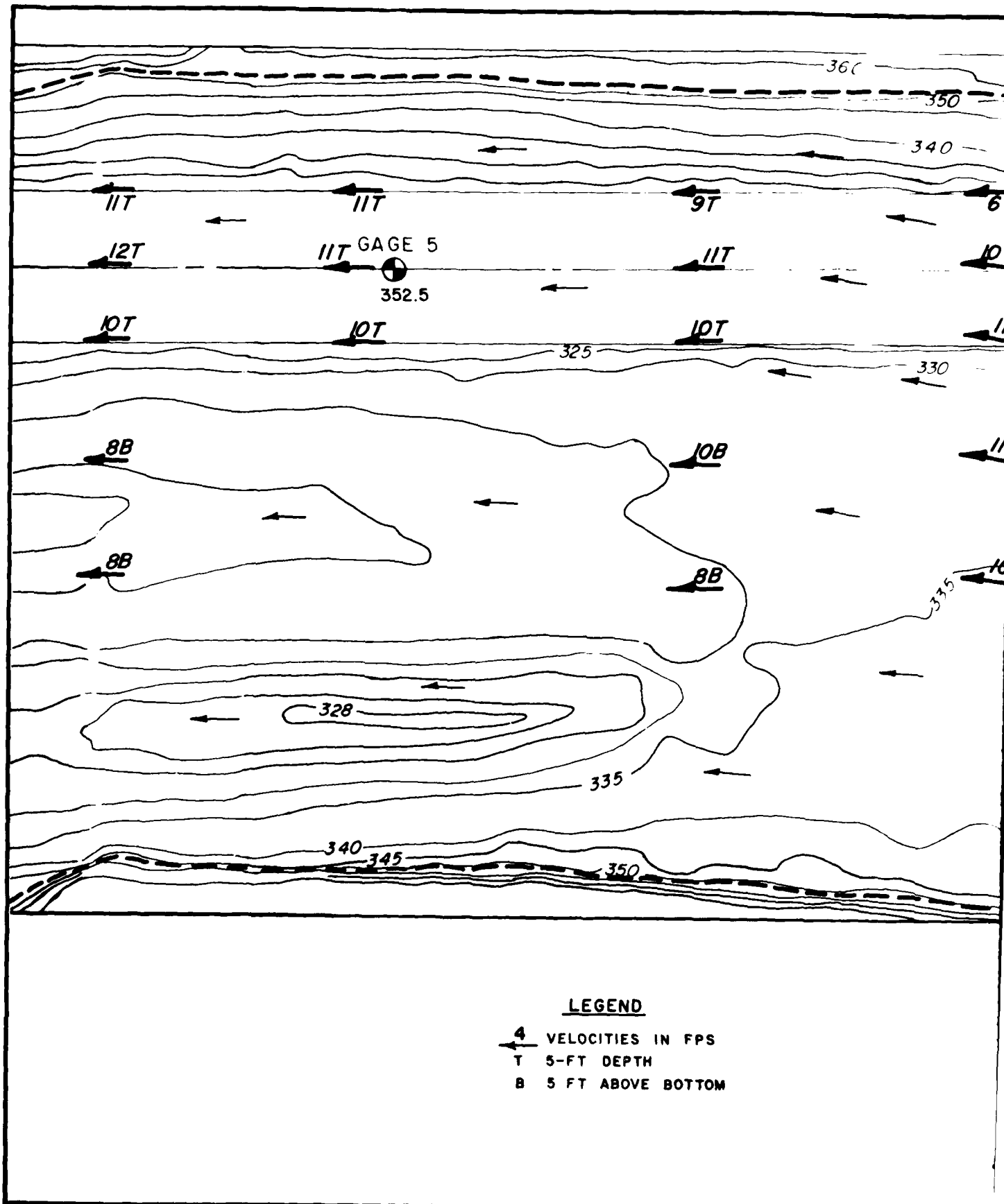


210-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 20

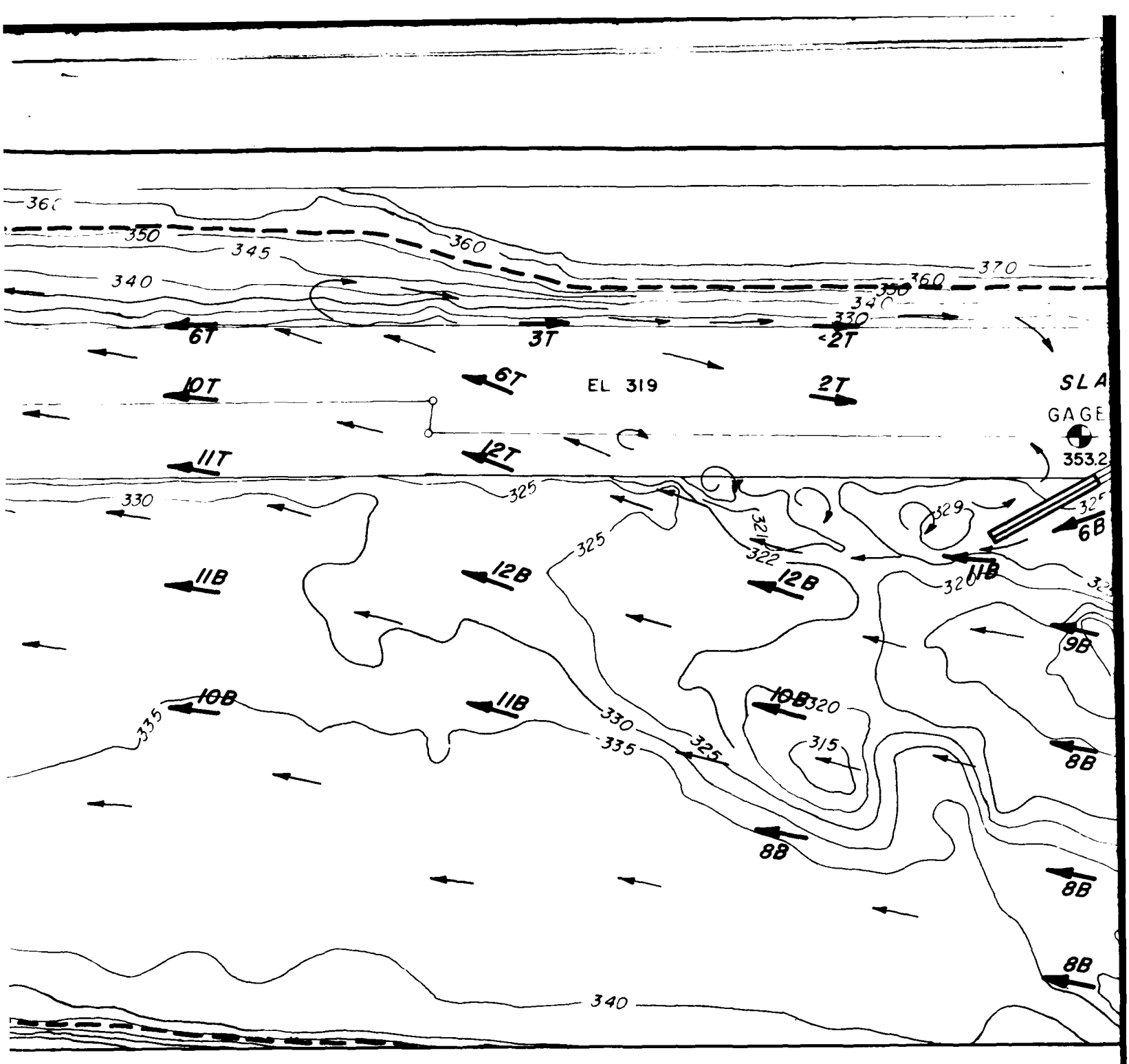


LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



SCALE

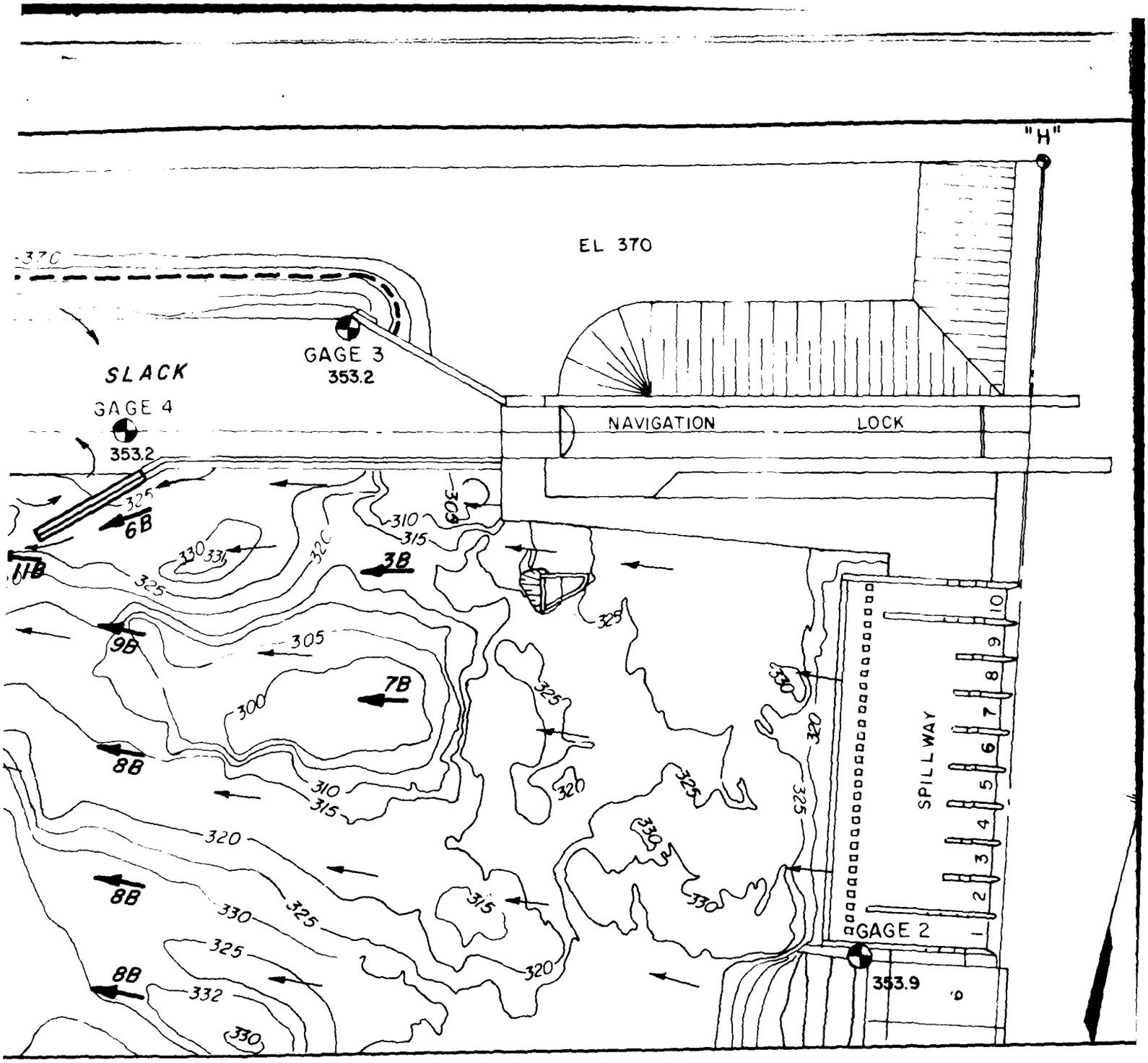
0 100 200 300 400 500 FT

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



W DISTRIBUTION

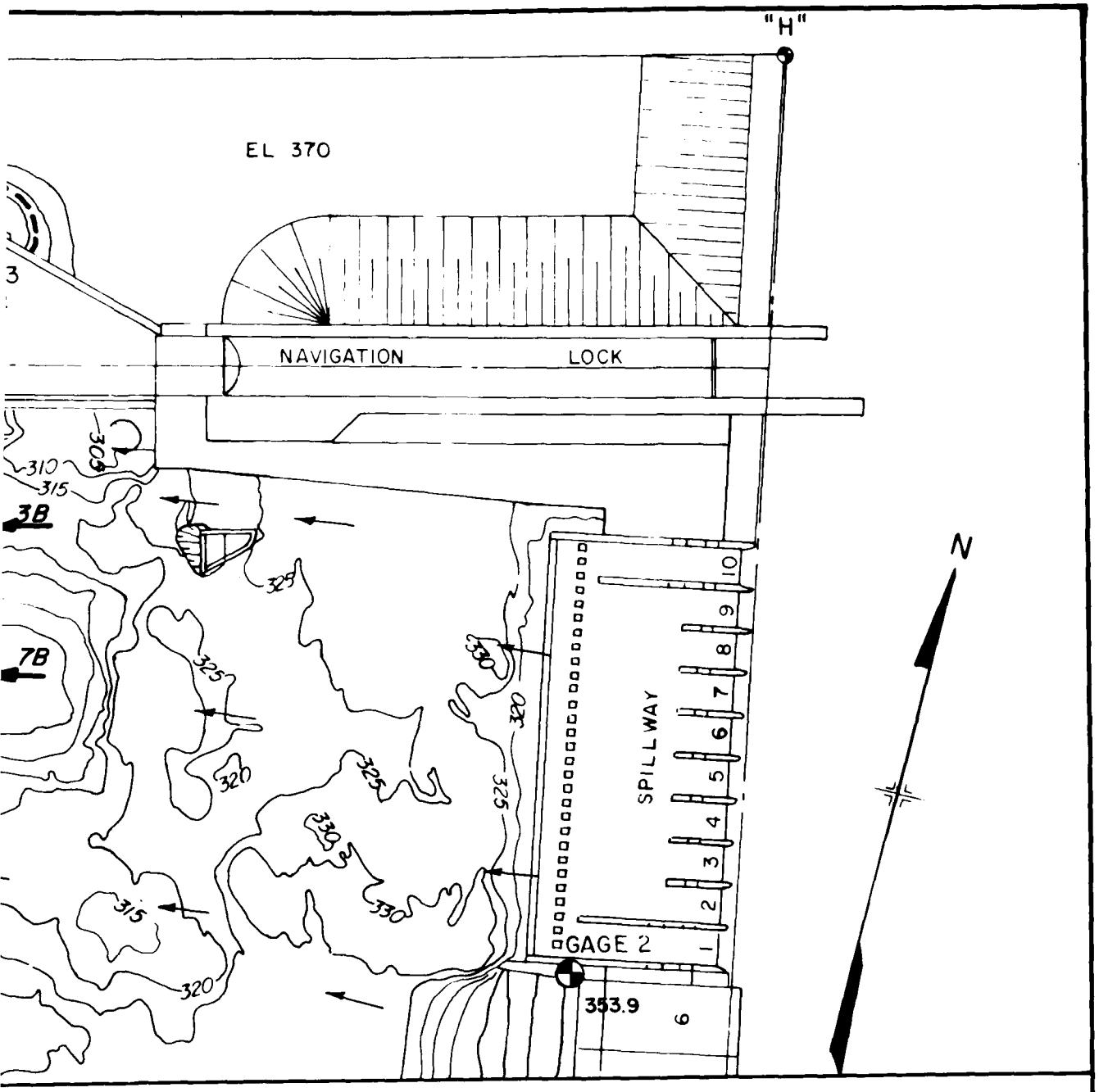
TO 10	119 200 CFS
S 1 TO 3	45 300 CFS
S 4 TO 6	55 500 CFS

210-FT EXTENSION TO

FLOW CONDIT

RIVER DISCHA

McNARY

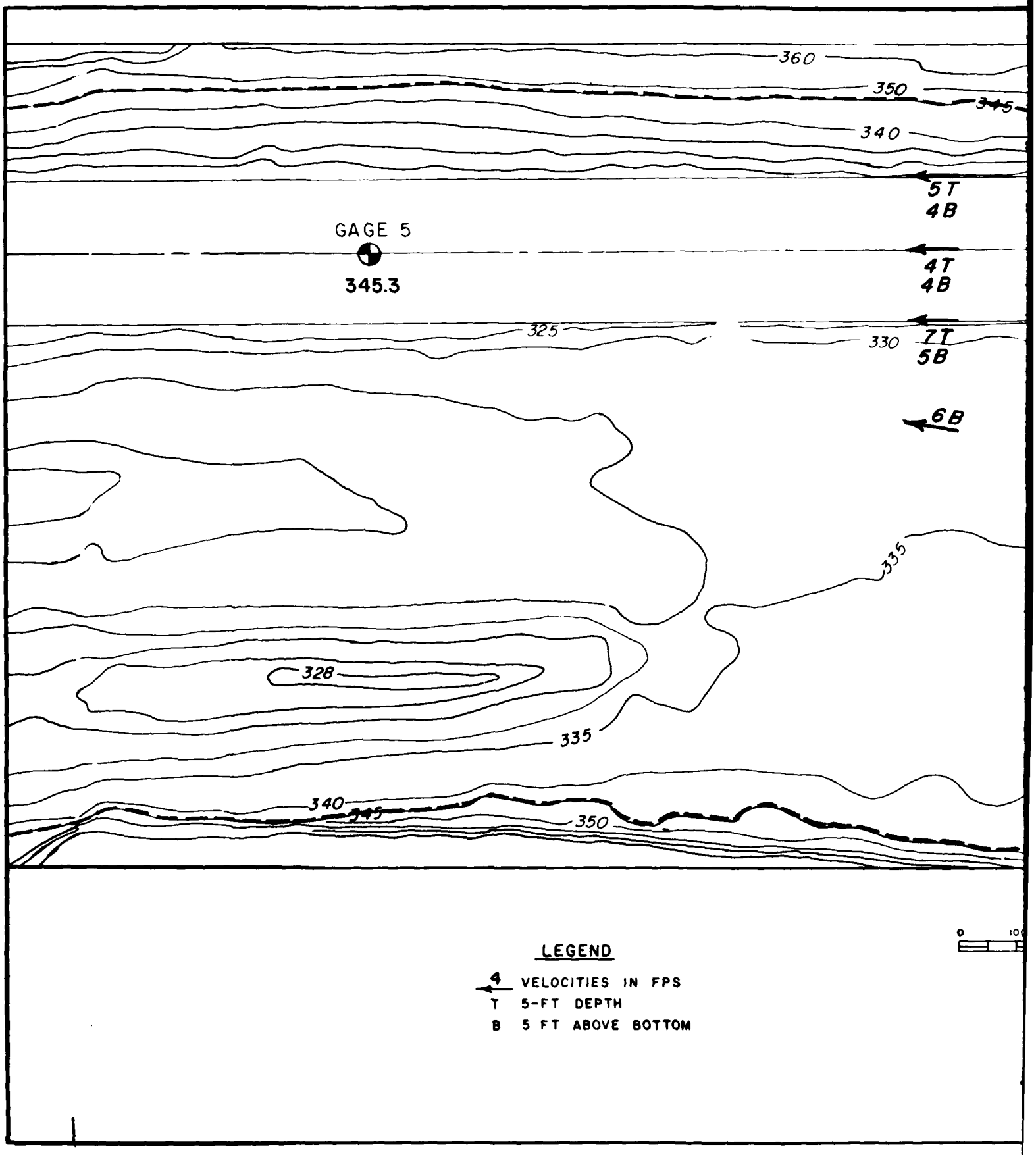


210-FT EXTENSION TO GUIDE WALL

FLOW CONDITIONS

RIVER DISCHARGE 220 000 CFS
McNARY POOL EL 335

PLATE 21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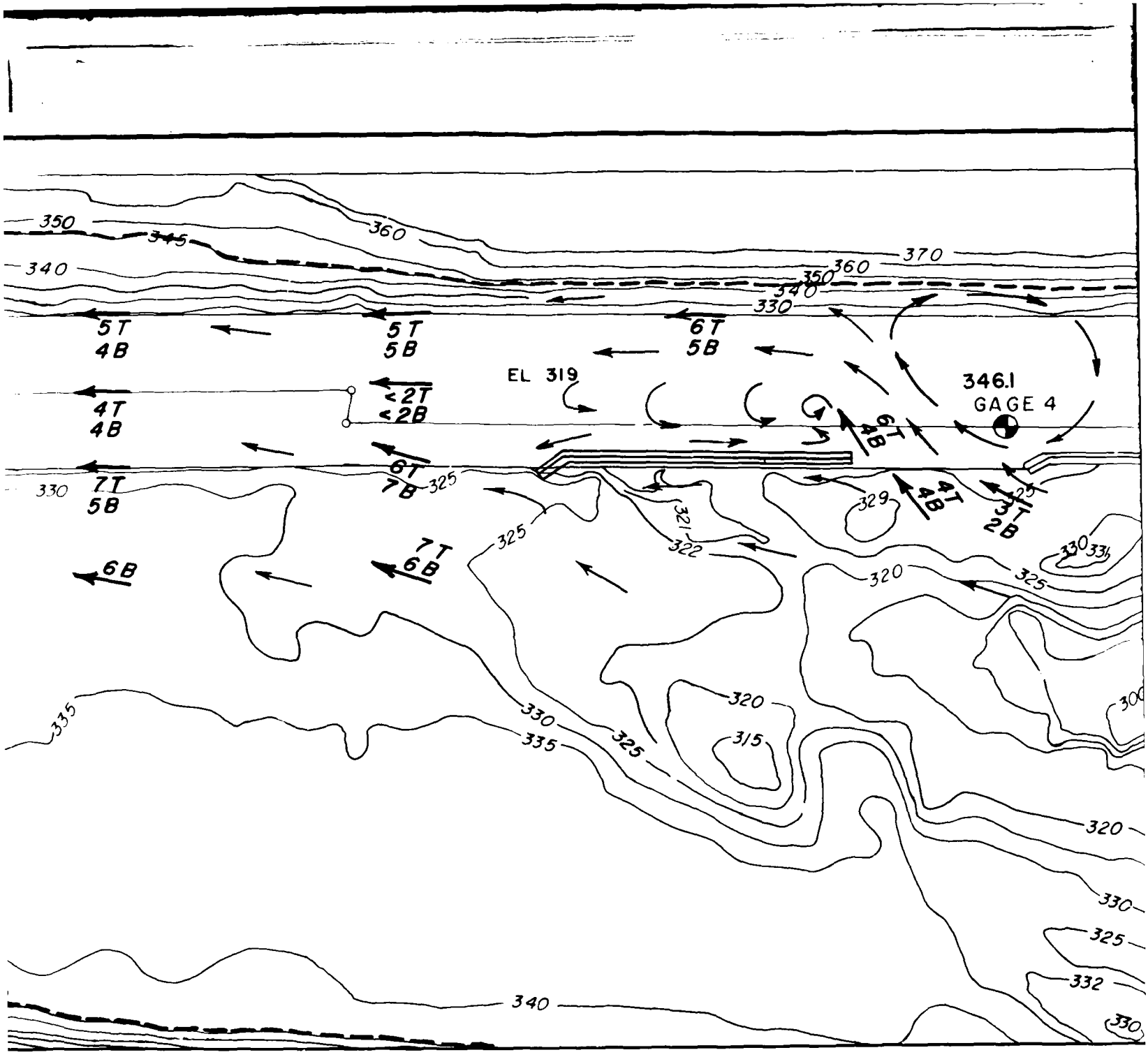
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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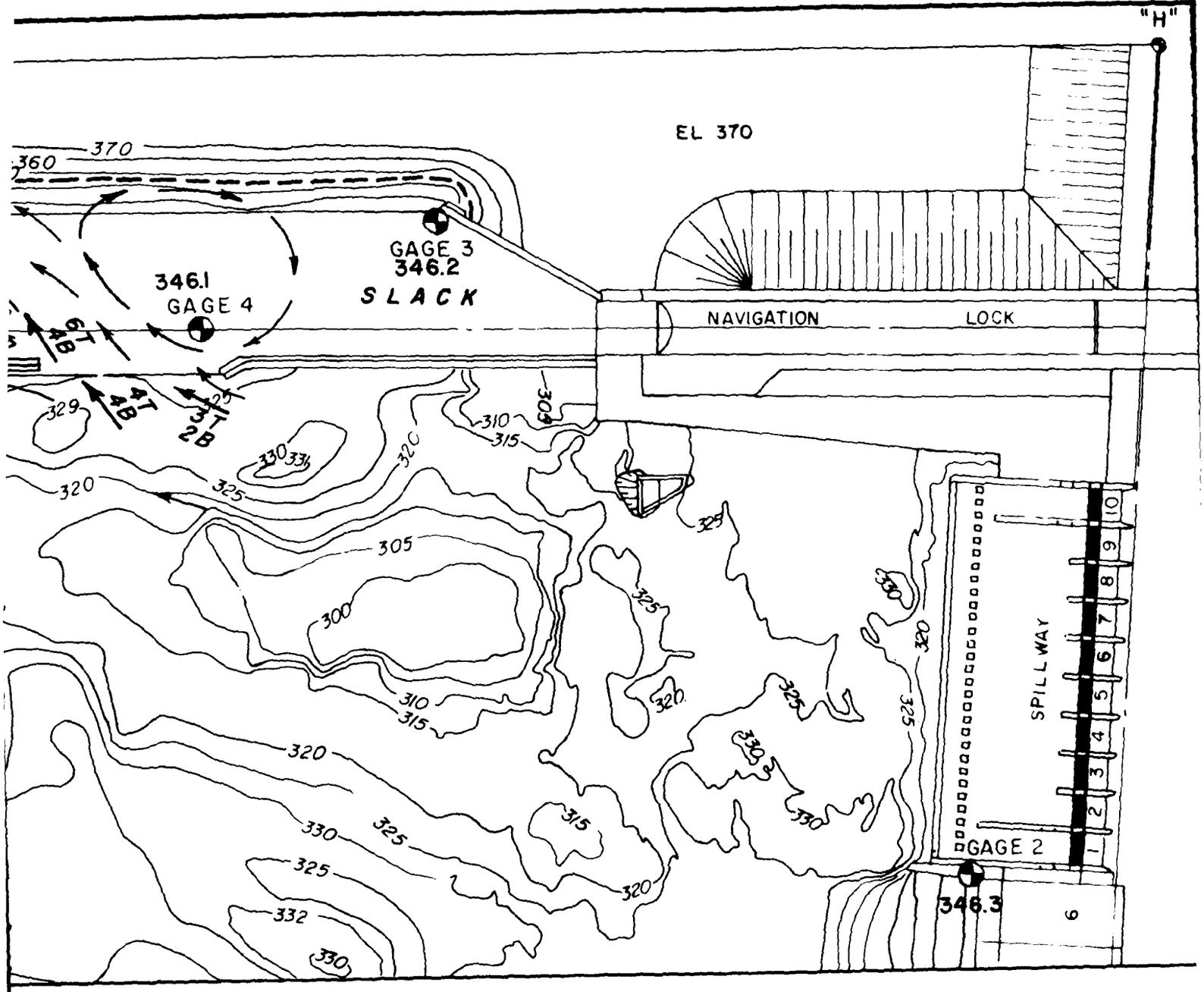
FLOW DISTRIBUTION

		CLOS
SPILLWAY BAYS	1 TO 10	
POWERHOUSE UNITS	1 TO 3	43 300 C
POWERHOUSE UNITS	4 TO 6	56 700 C



500-FT WALL WI

FLOW DISTRIBUTION

AYS	1 TO 10	CLOSED
E	UNITS 1 TO 3	43 300 CFS
E	UNITS 4 TO 6	56 700 CFS

FLOW CC

RIVER DISCHAR
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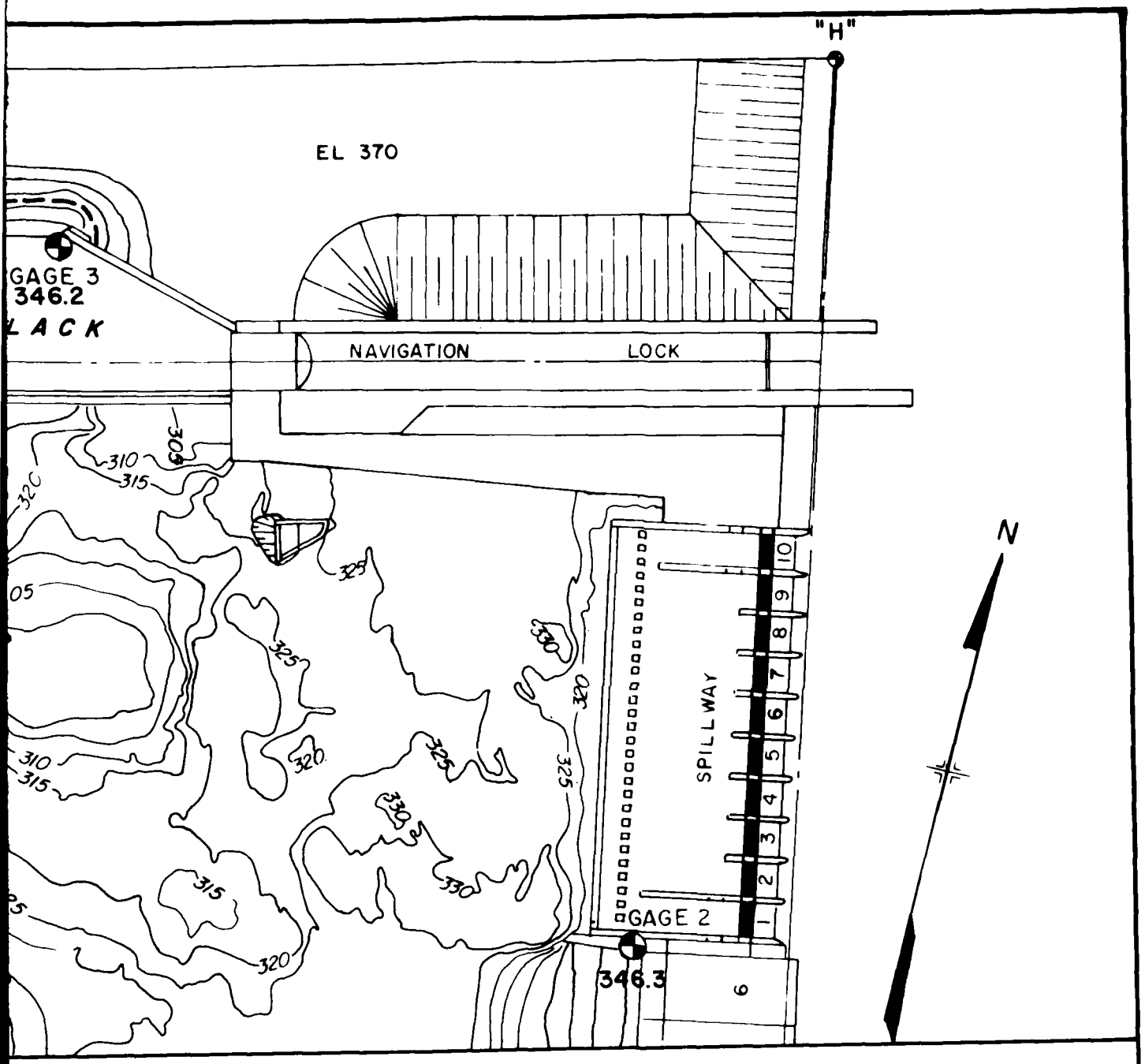
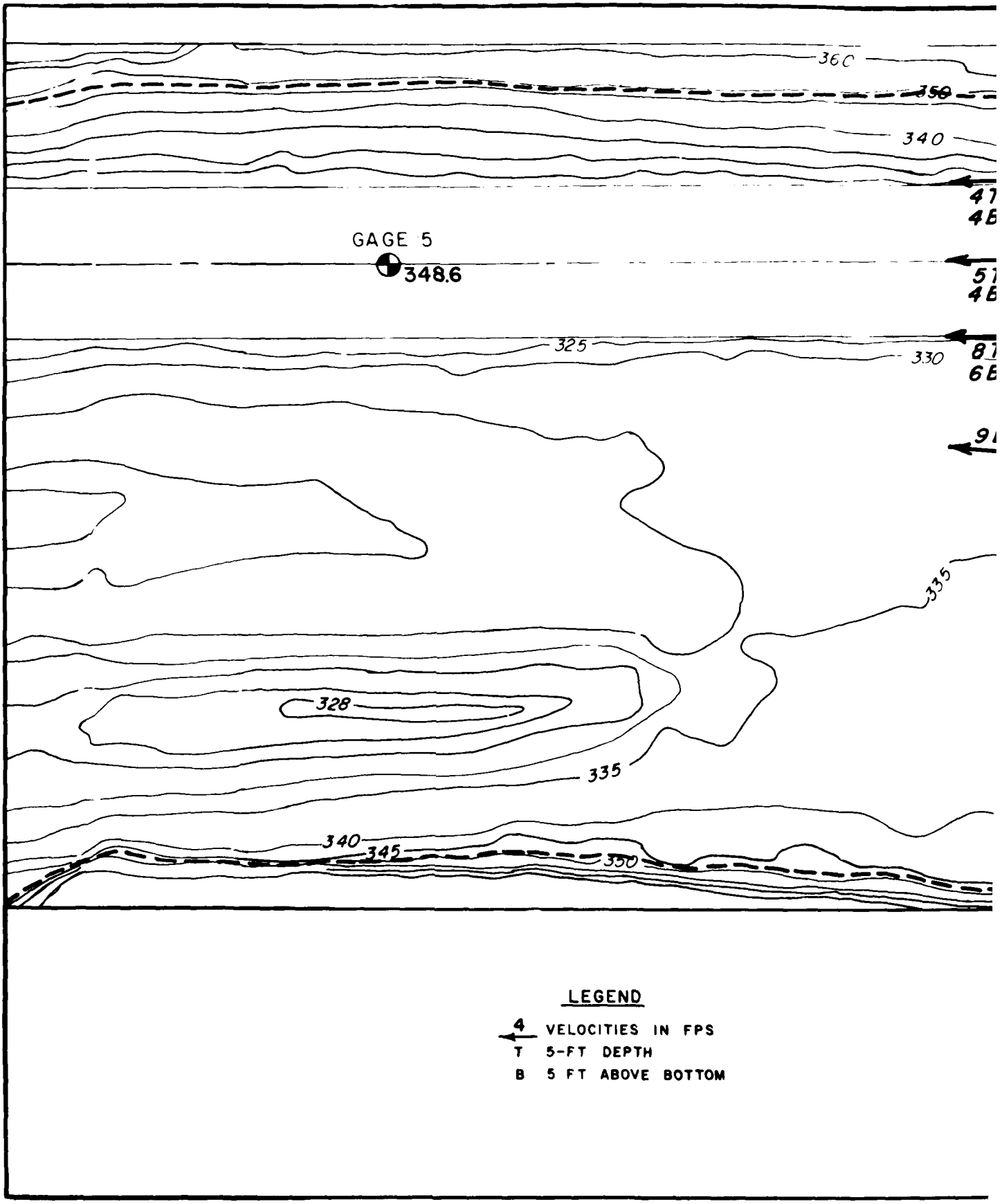


500-FT WALL WITH 300-FT SPACE

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 22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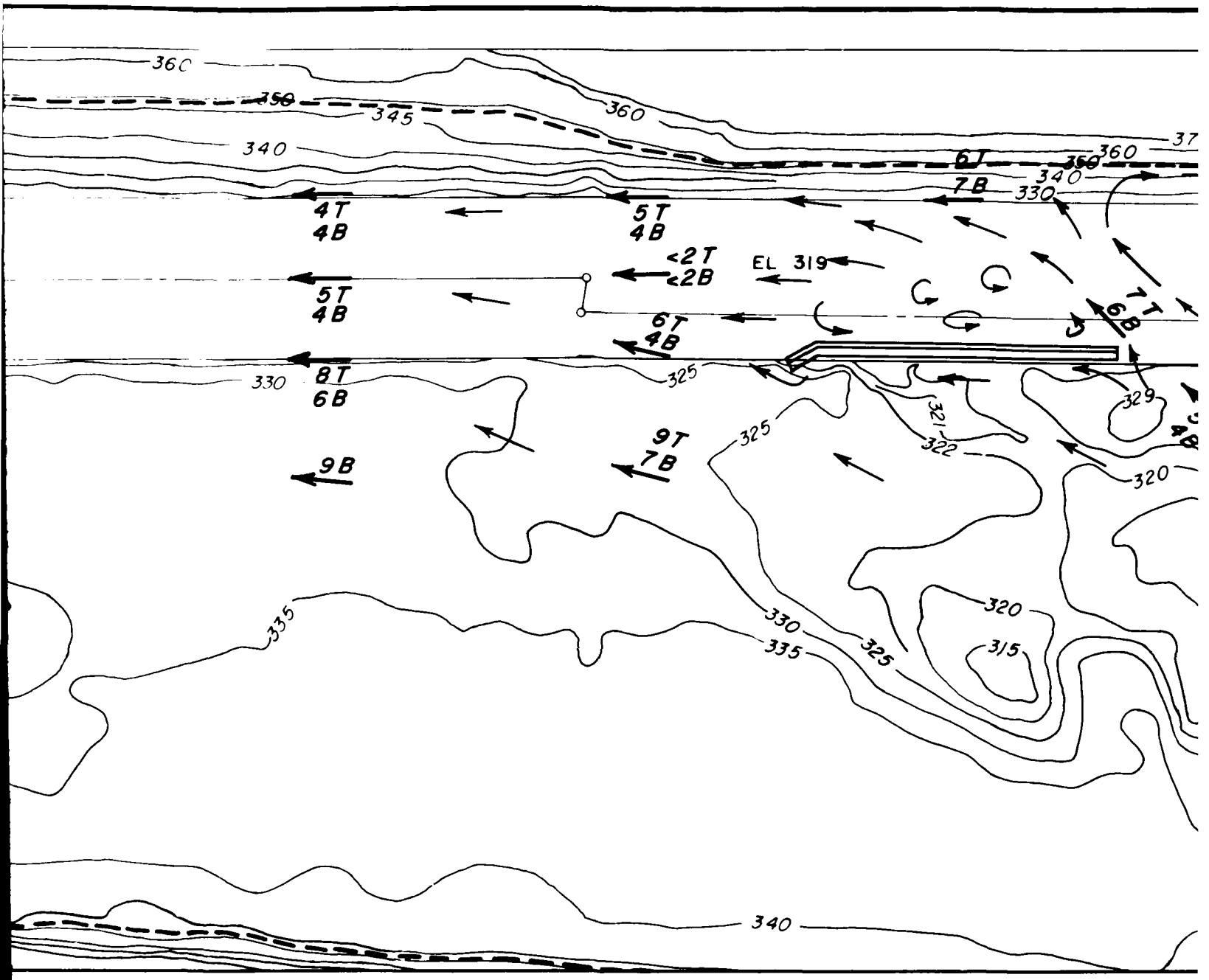
B 5 FT ABOVE BOTTOM



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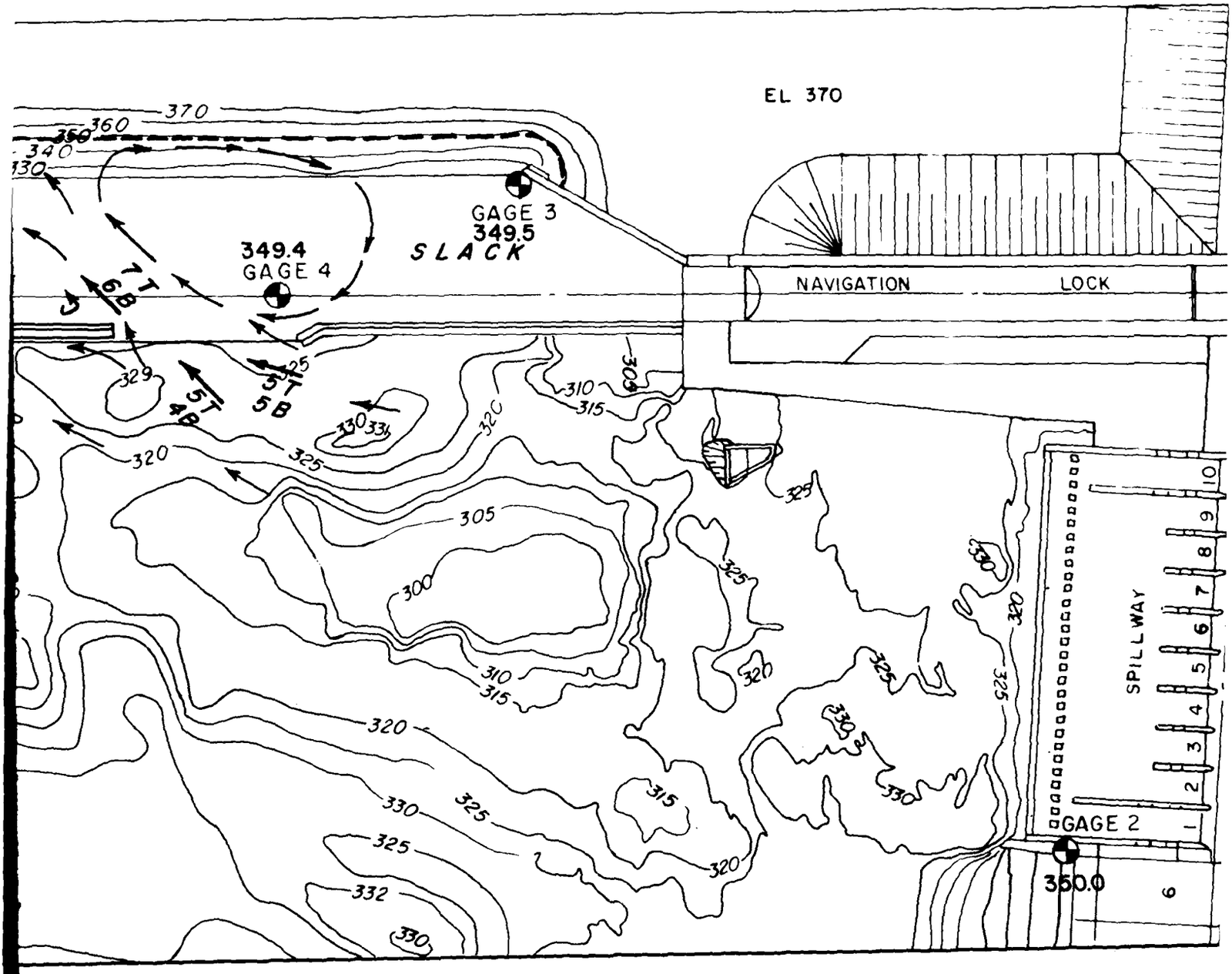
SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO

POWERHOUSE UNITS 4 TO



500-FT WAI

FLOW DISTRIBUTION

WAY BAYS 1 TO 10	50 000 CFS
ERHOUSE UNITS 1 TO 3	43 300 CFS
ERHOUSE UNITS 4 TO 6	56 700 CFS

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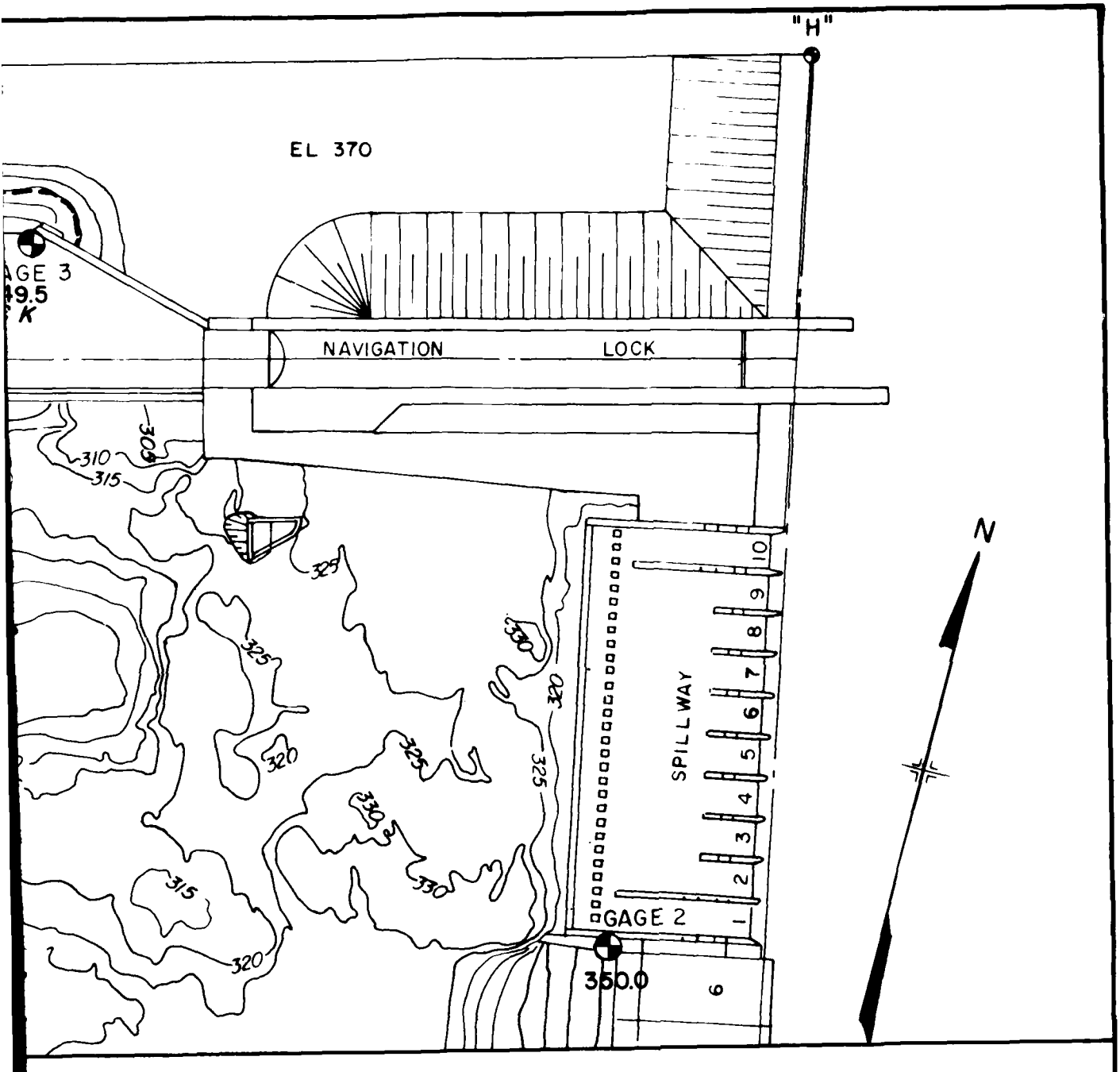
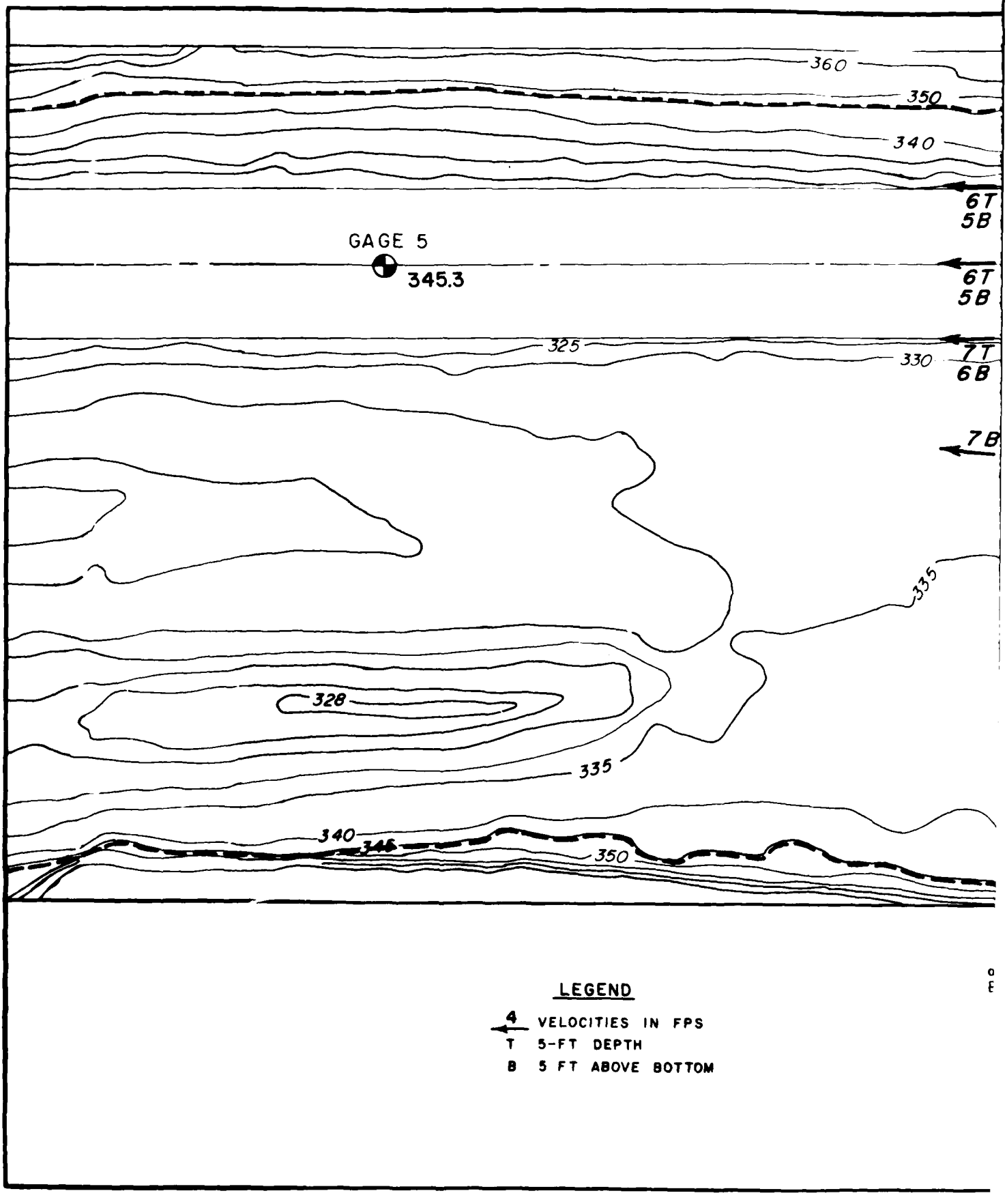


500-FT WALL WITH 300-FT SPACE

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 23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4 VELOCITIES IN FPS
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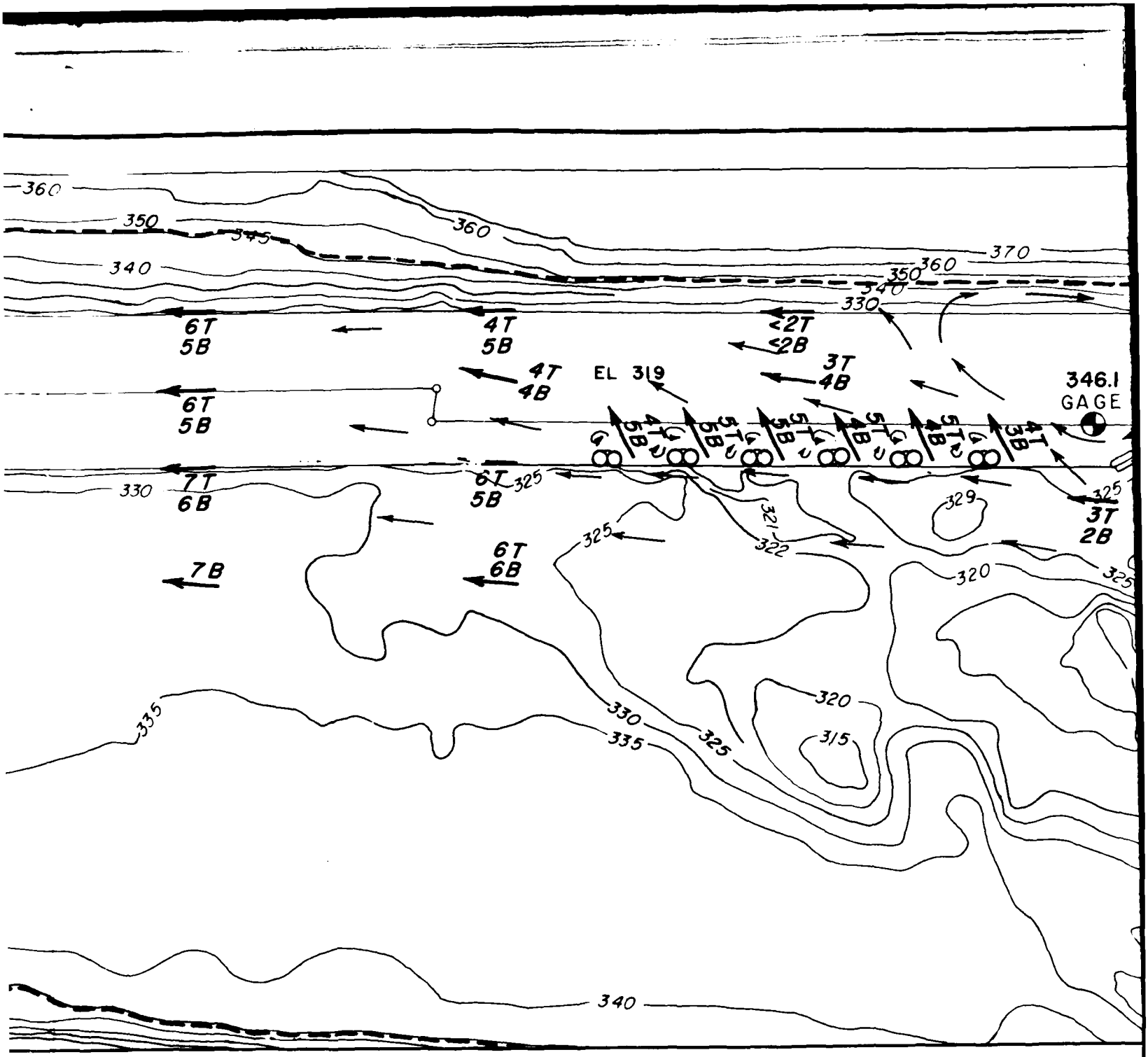
B 5 FT ABOVE BOTTOM



SCALE

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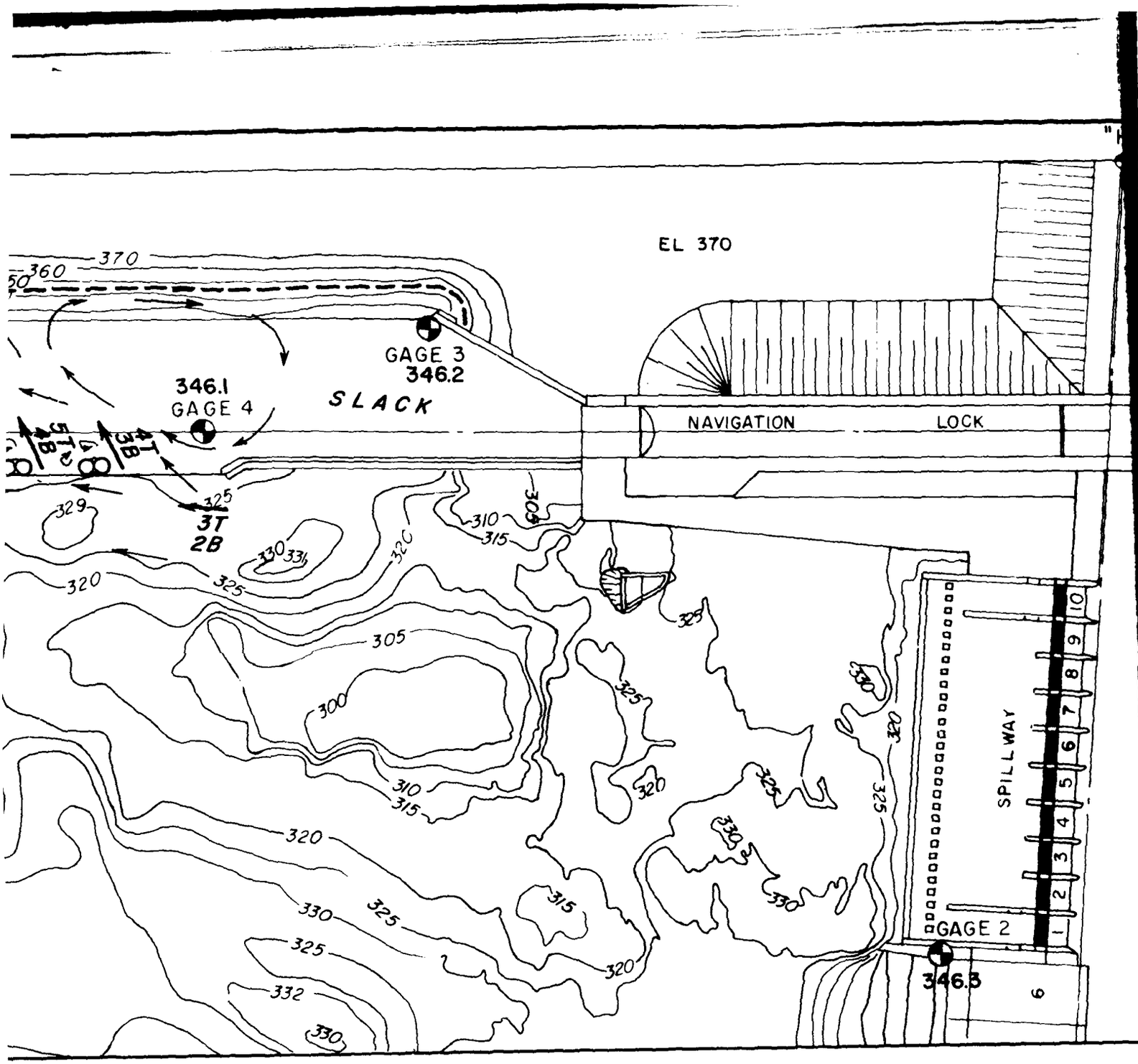
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



SIX UNITS WI

FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
SE UNITS 1 TO 3	43 300 CFS
SE UNITS 4 TO 6	56 700 CFS

FLOW C

RIVER DISCHA
McNARY P

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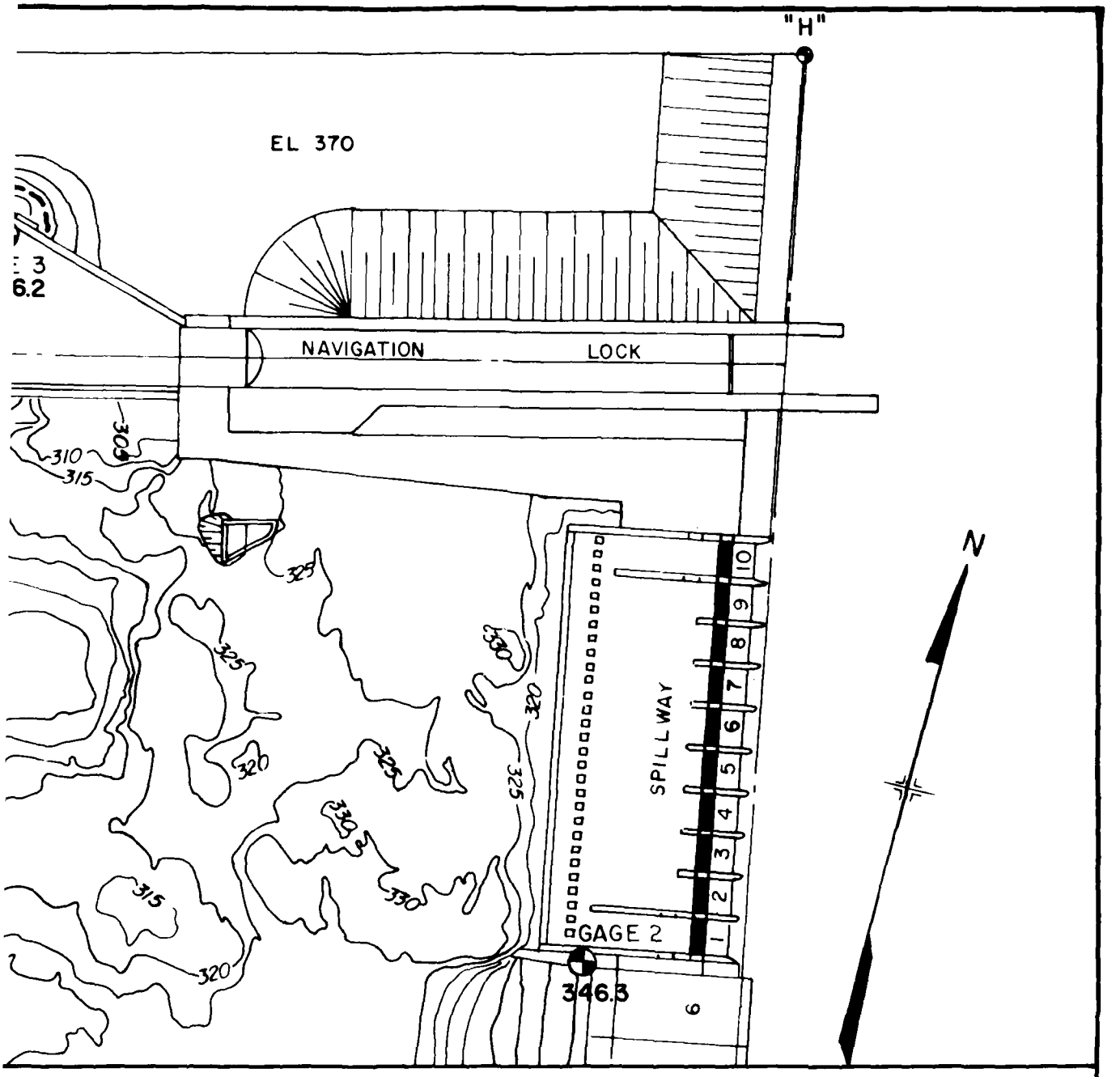
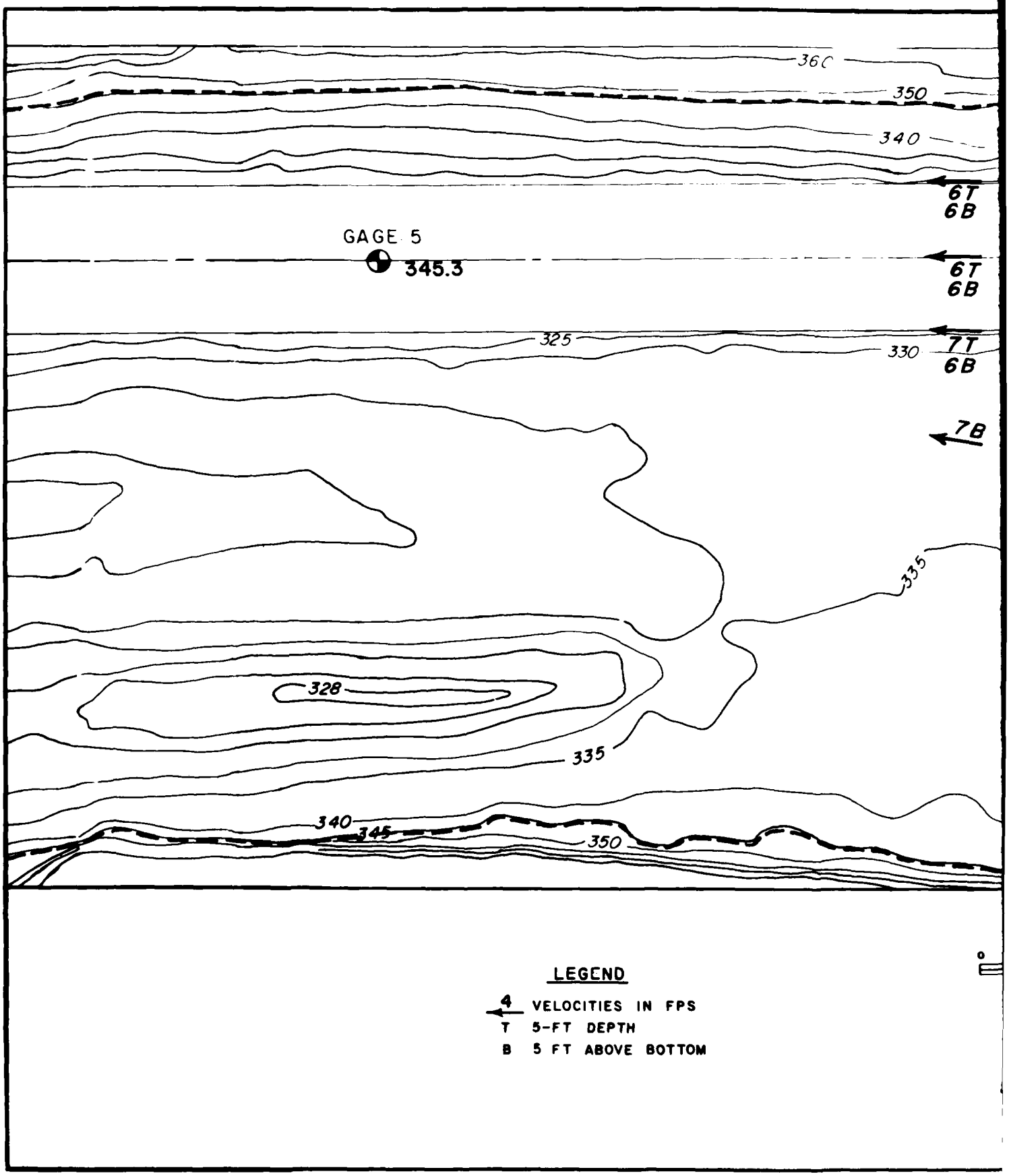


SIX UNITS WITH 70-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 24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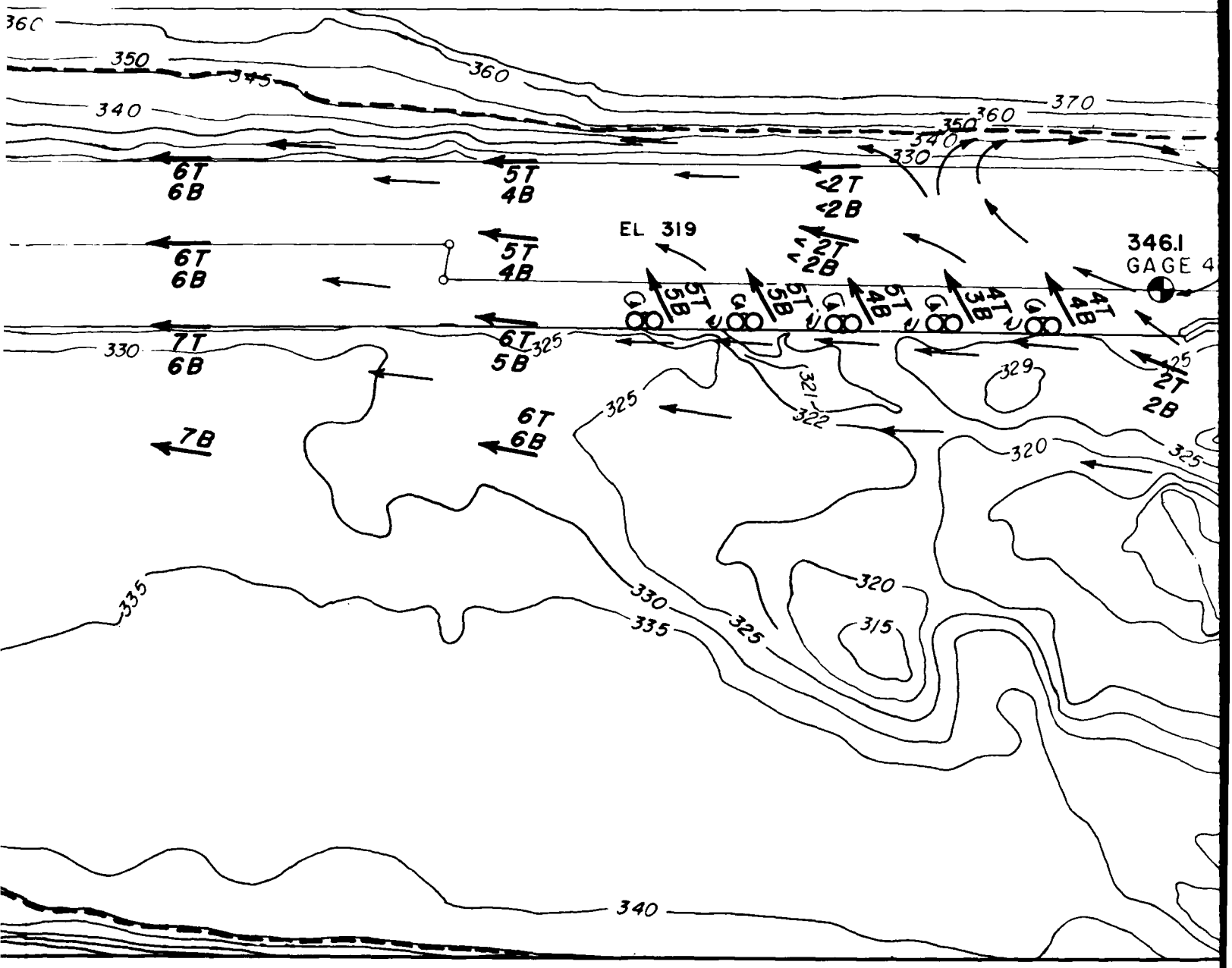
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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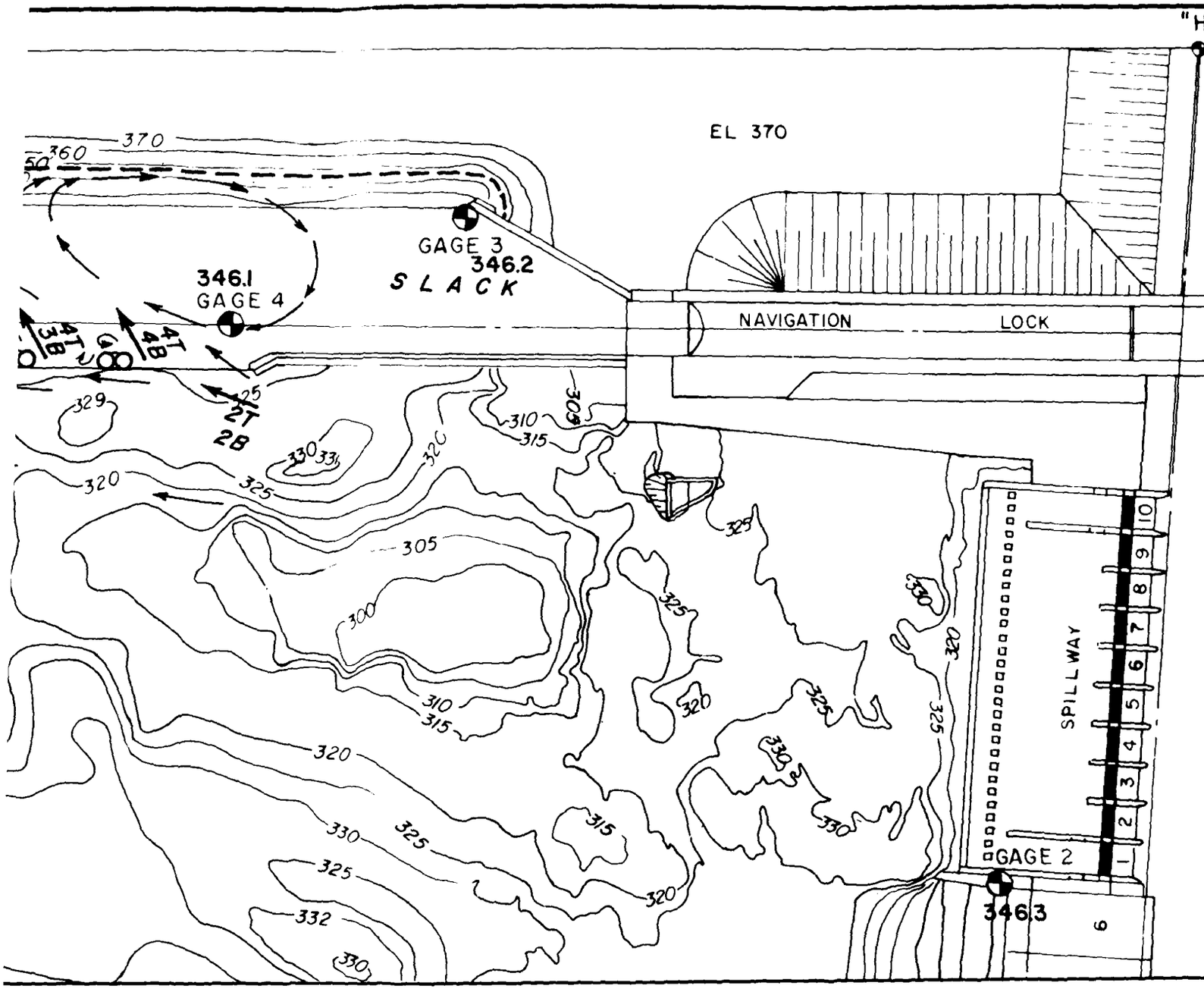
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



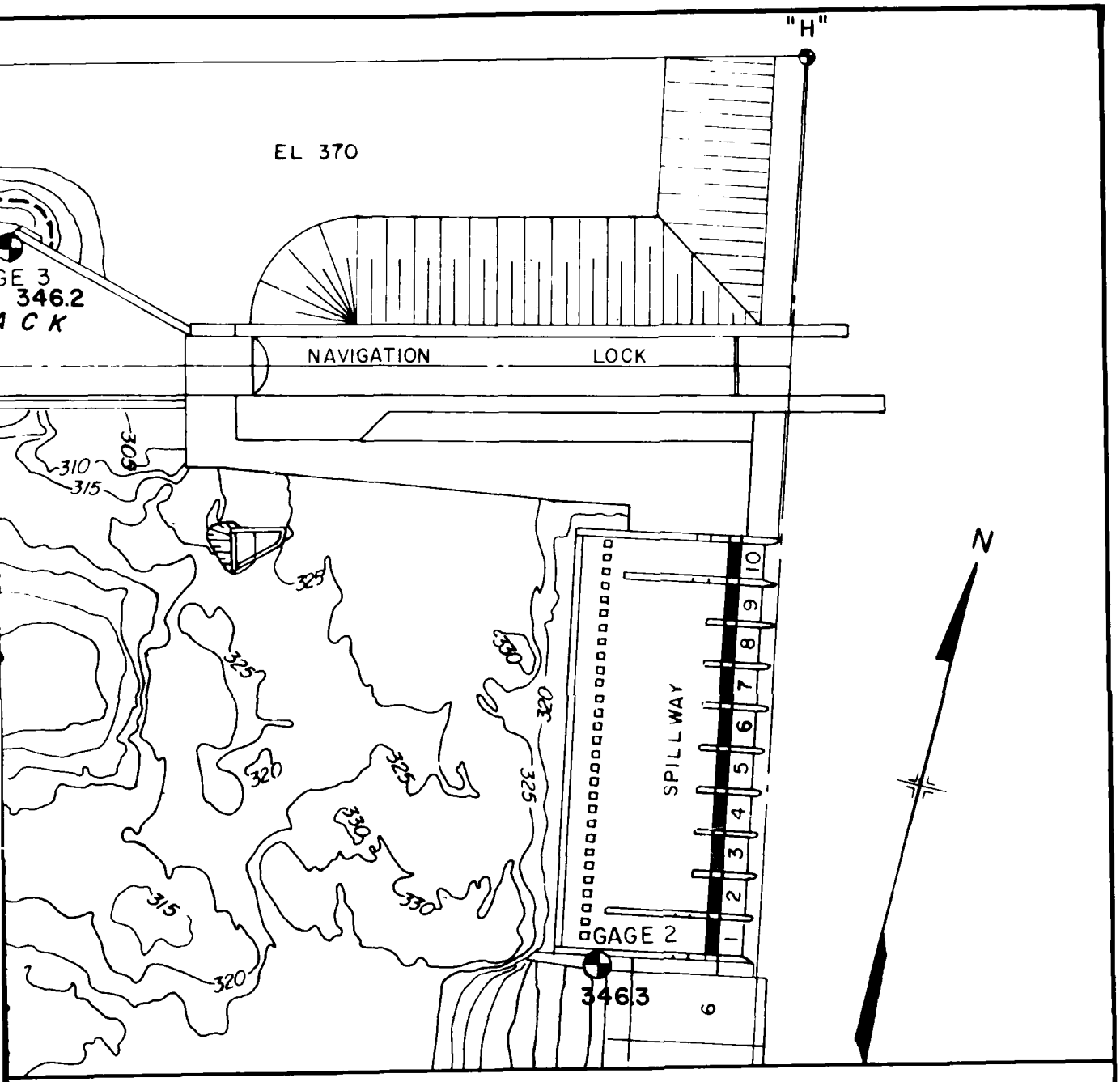
FIVE UNITS WITI

FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
)USE UNITS 1 TO 3	43 300 CFS
USE UNITS 4 TO 6	56 700 CFS

FLOW C

RIVER DISCHA
McNARY F

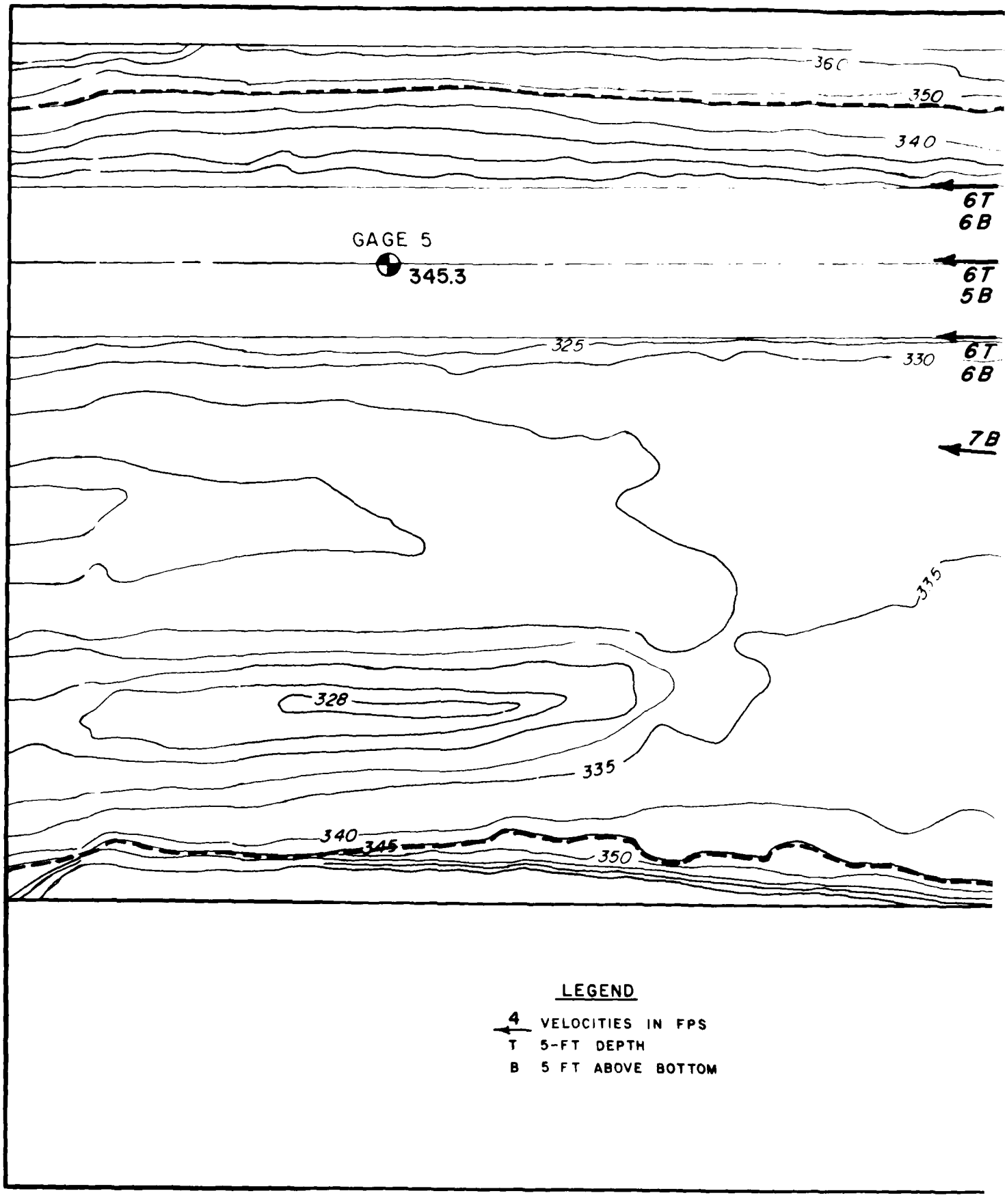


FIVE UNITS WITH 100-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 25

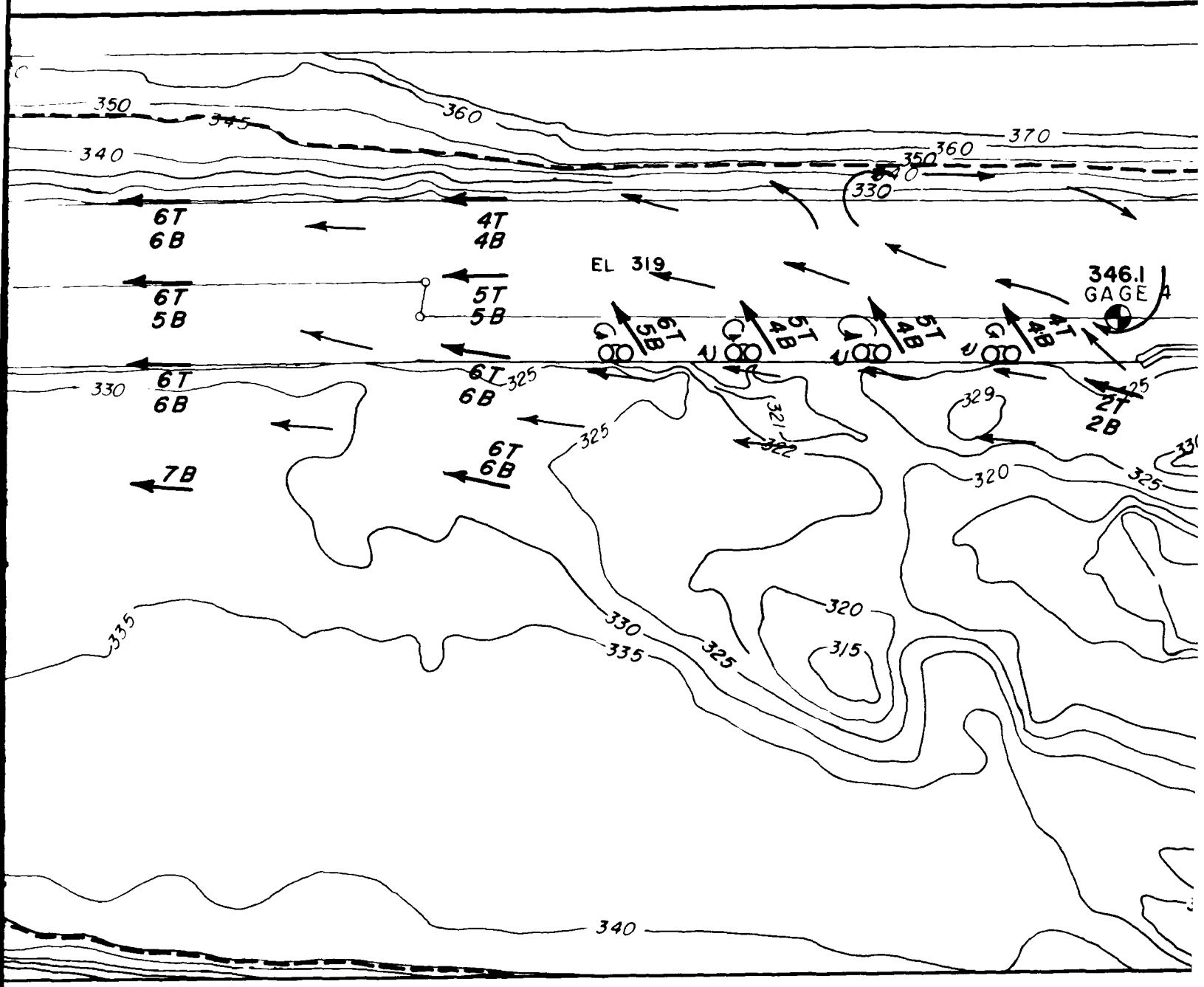


LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM



SCALE

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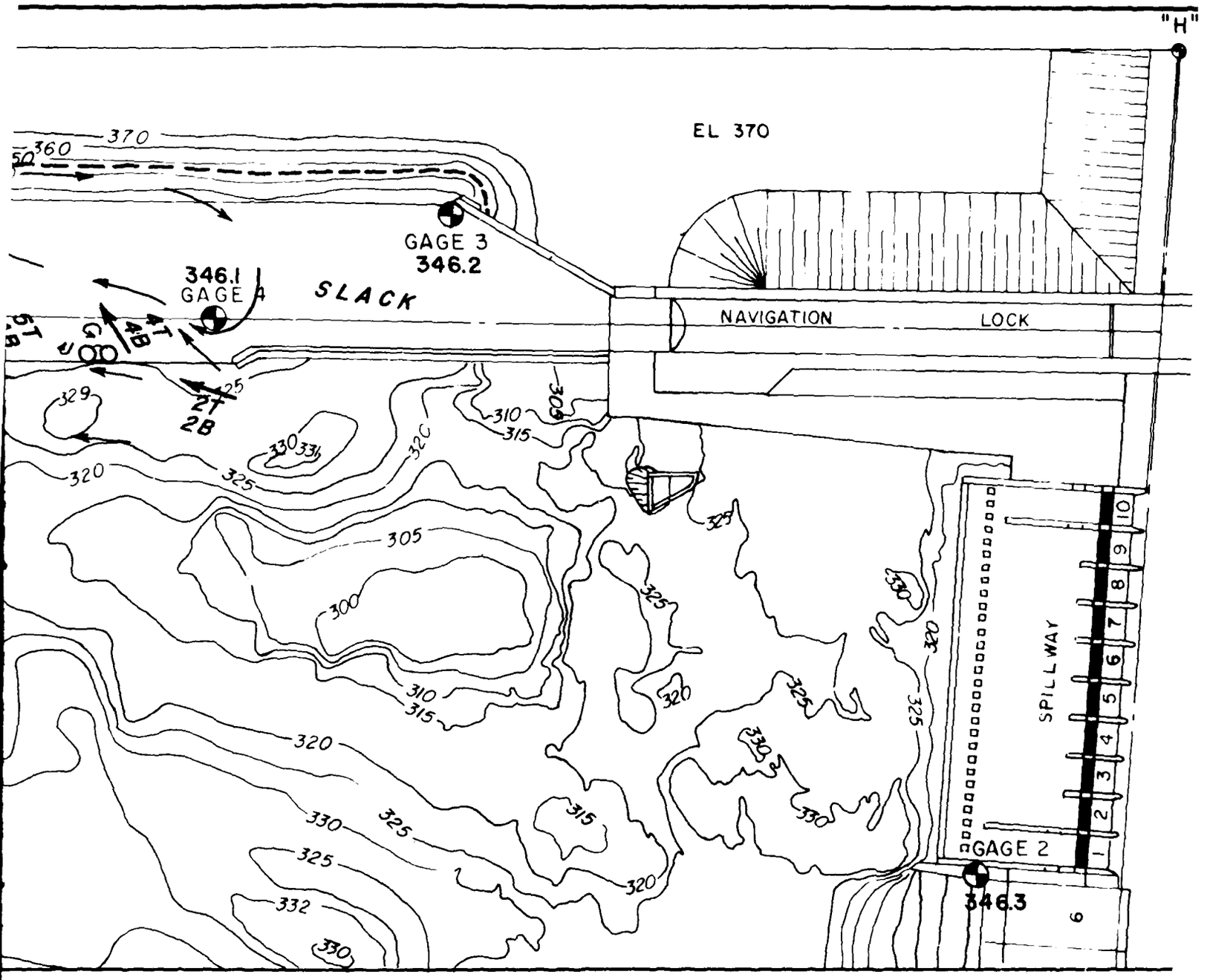
FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
SE UNITS 1 TO 3	43 300 CFS
SE UNITS 4 TO 6	56 700 CFS

FOUR UNITS WIT

FLOW

RIVER DISCH
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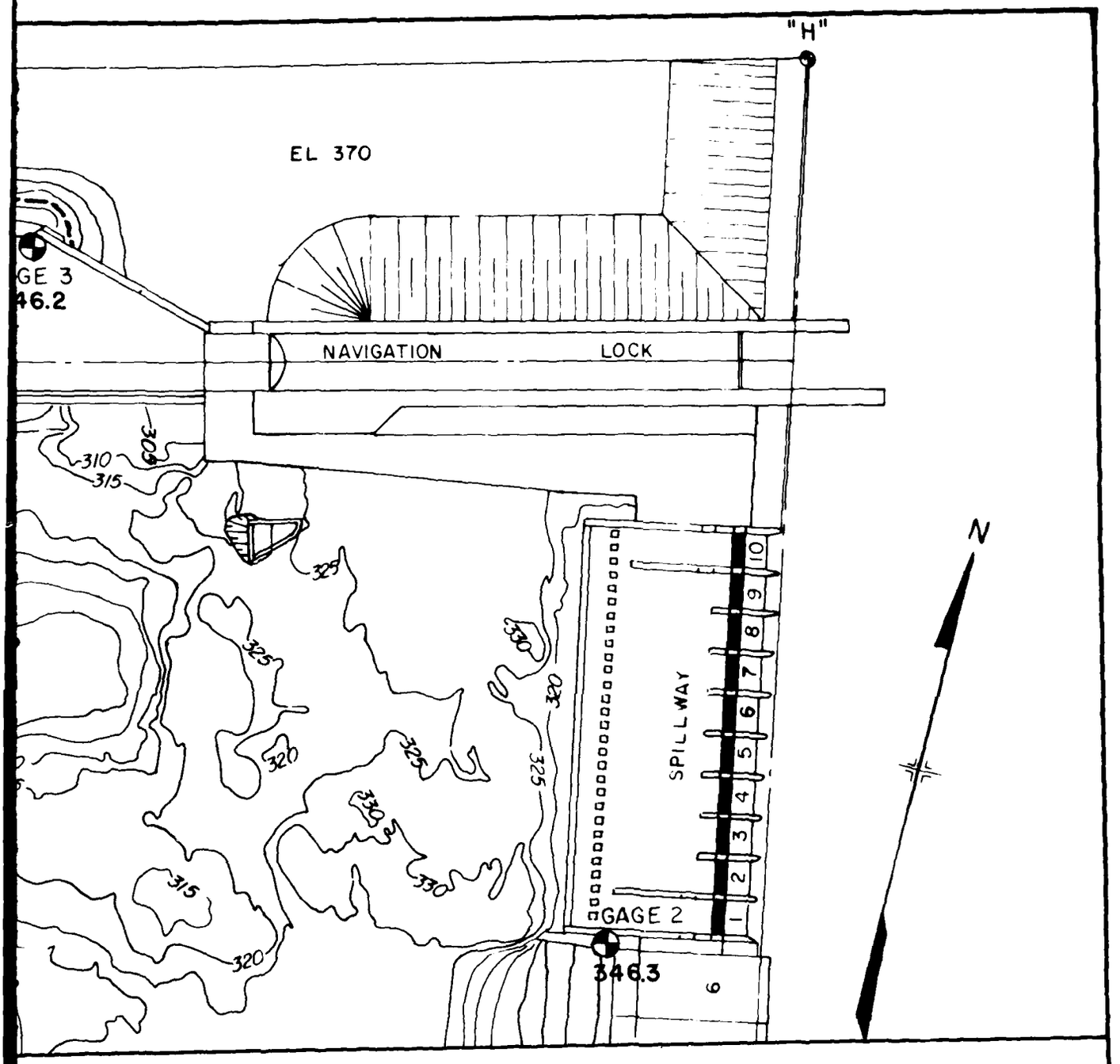
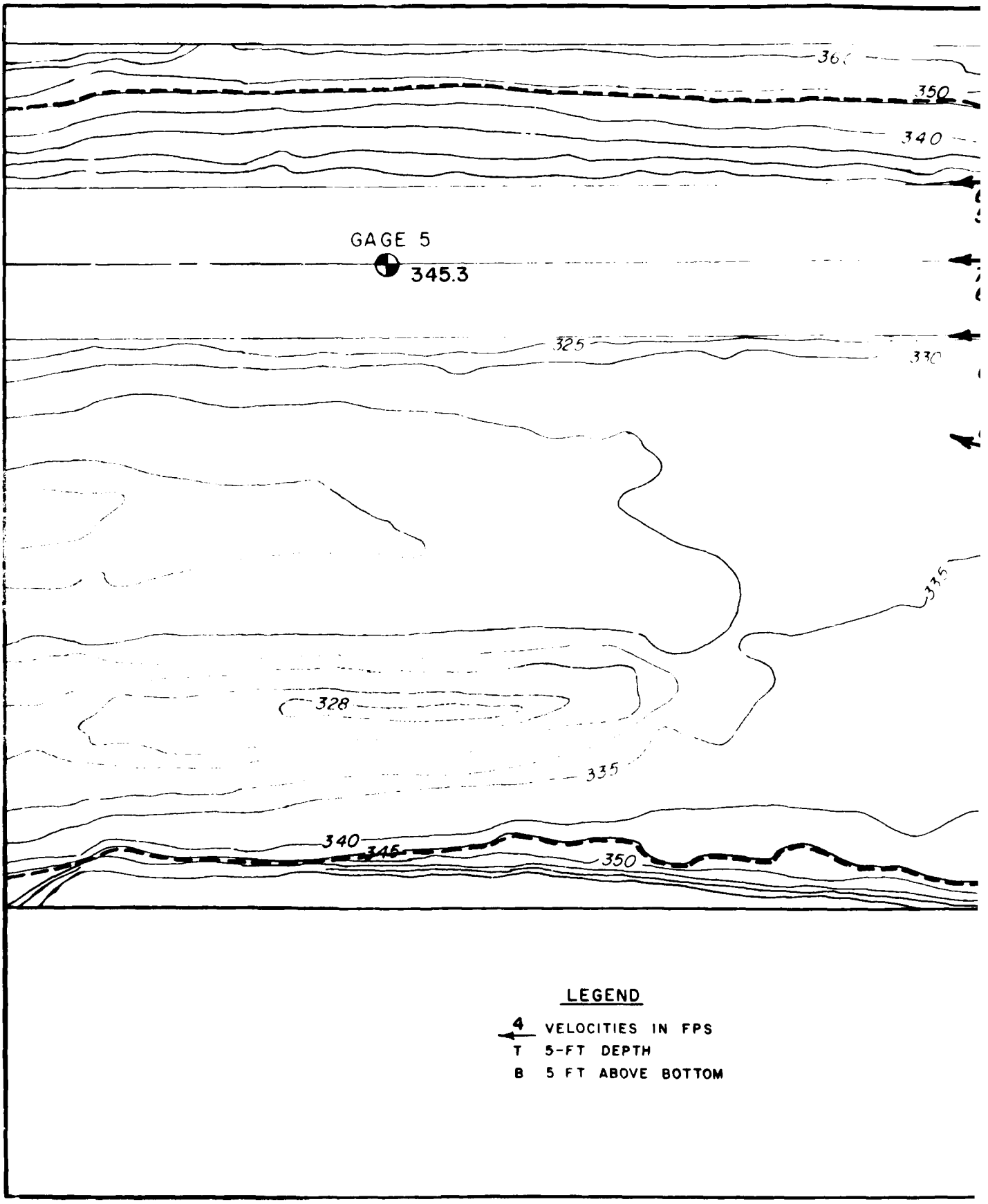


FOUR UNITS WITH 150-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 26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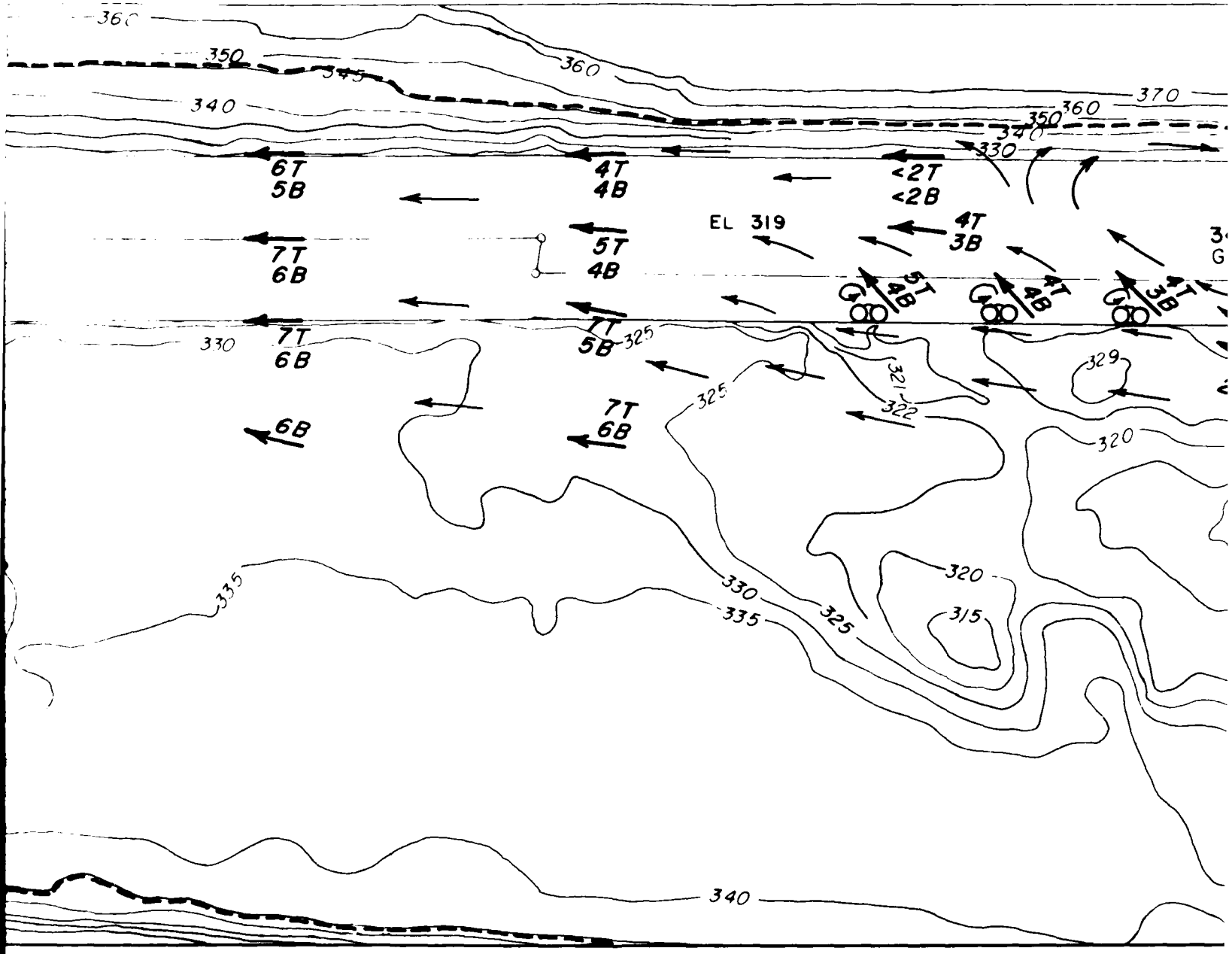
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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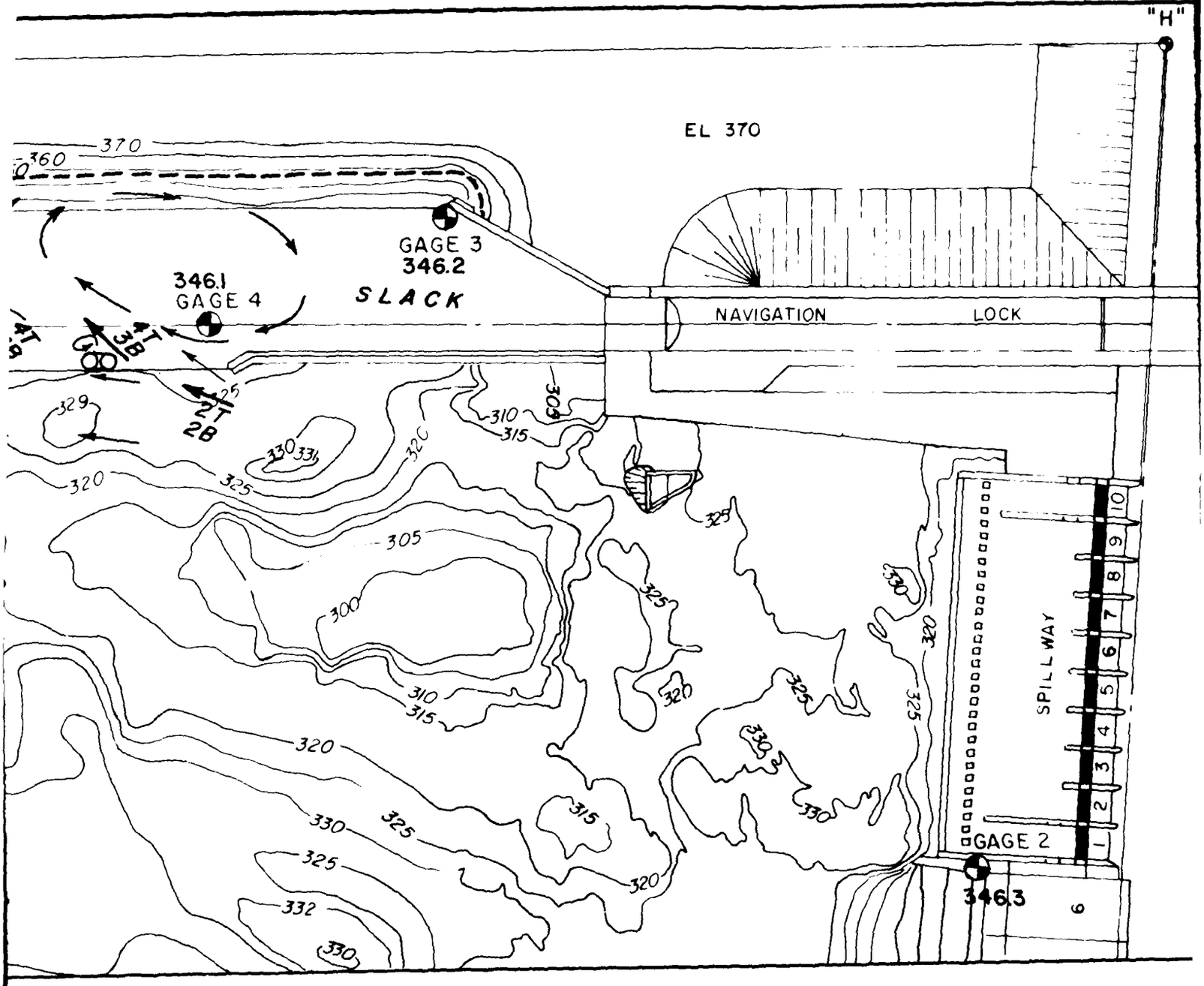
FLOW DISTRIB

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



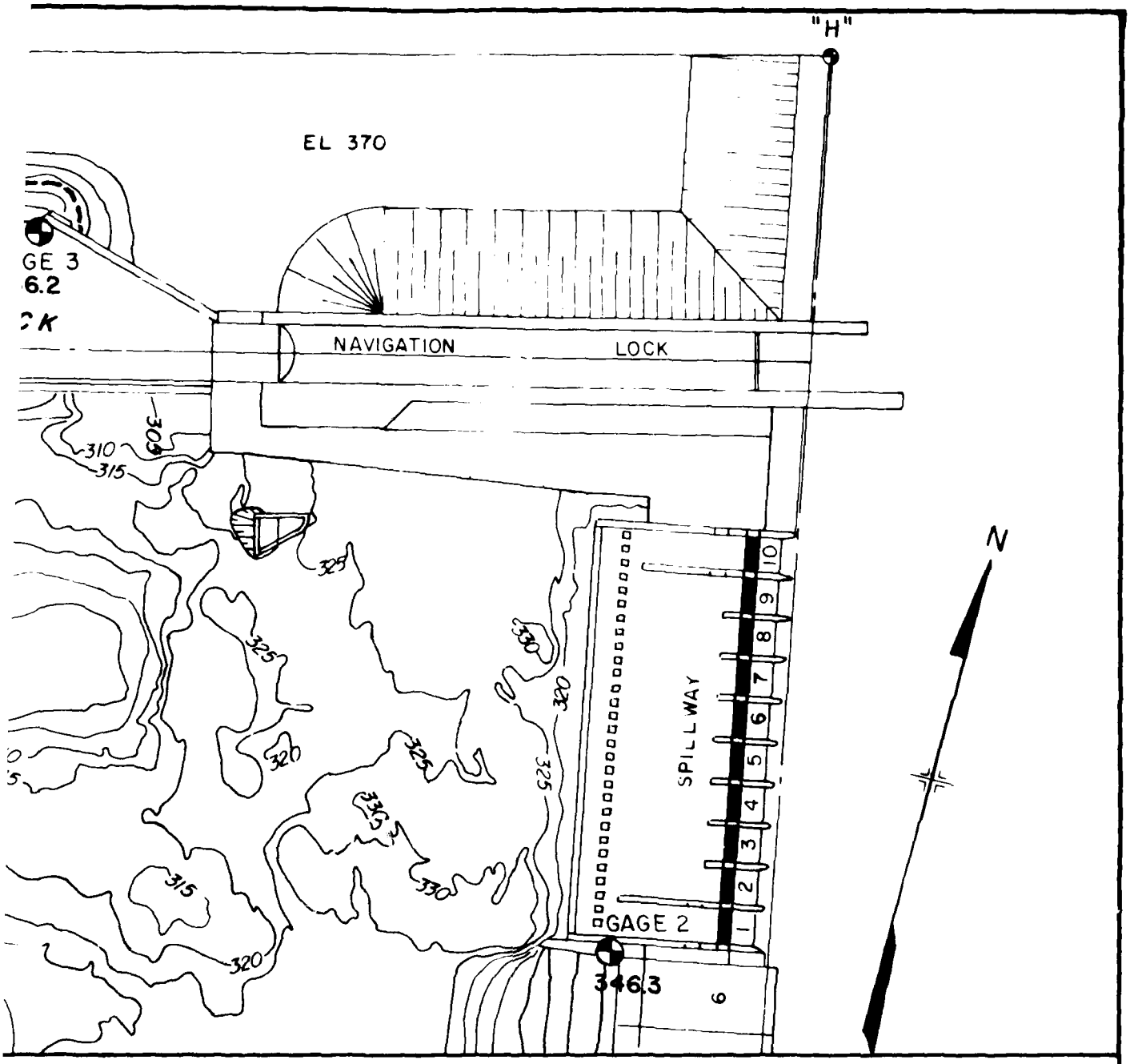
THREE UNITS WITH

FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
SE UNITS 1 TO 3	43 300 CFS
SE UNITS 4 TO 6	56 700 CFS

FLOW C

RIVER DISCHA
McNARY P

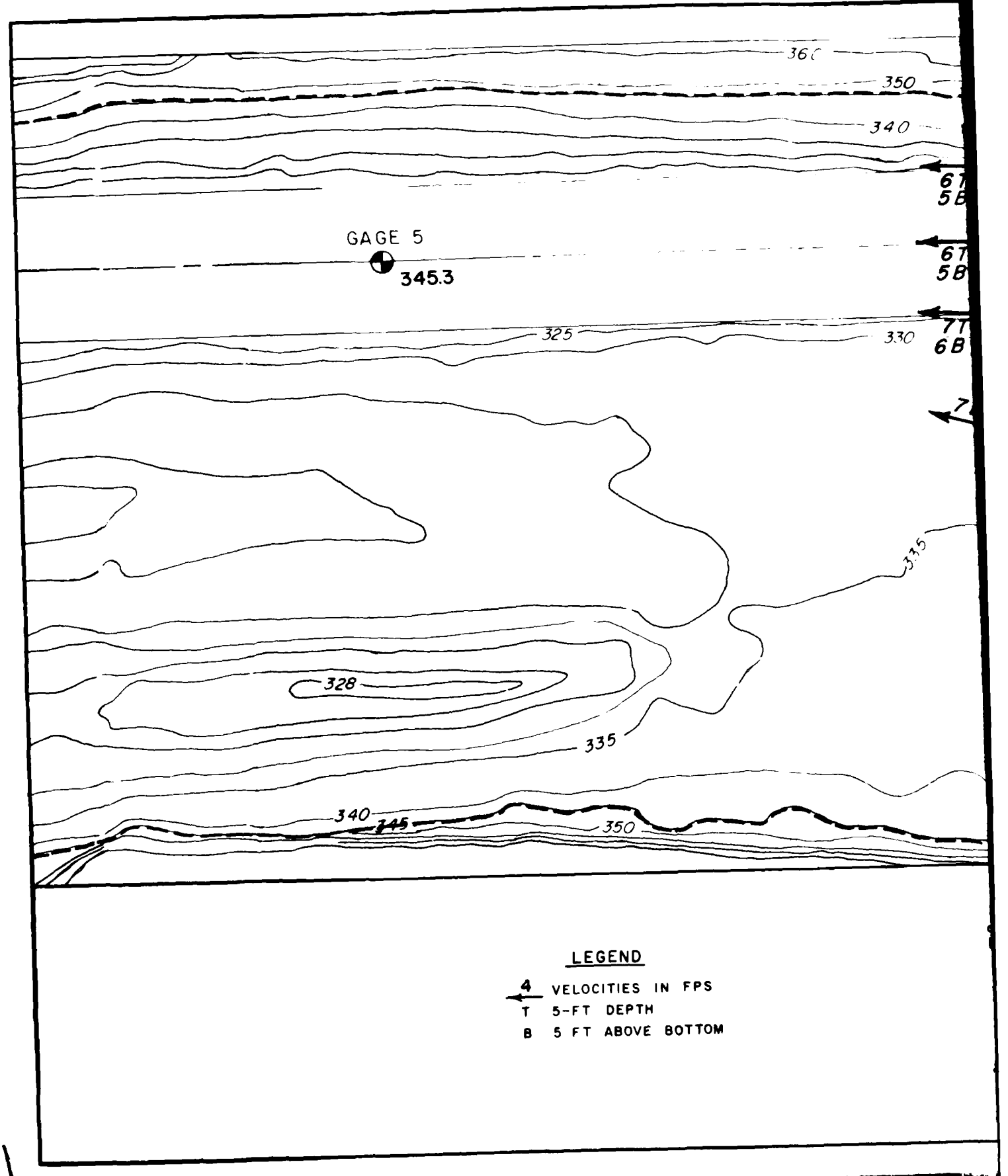


THREE UNITS WITH 150-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 27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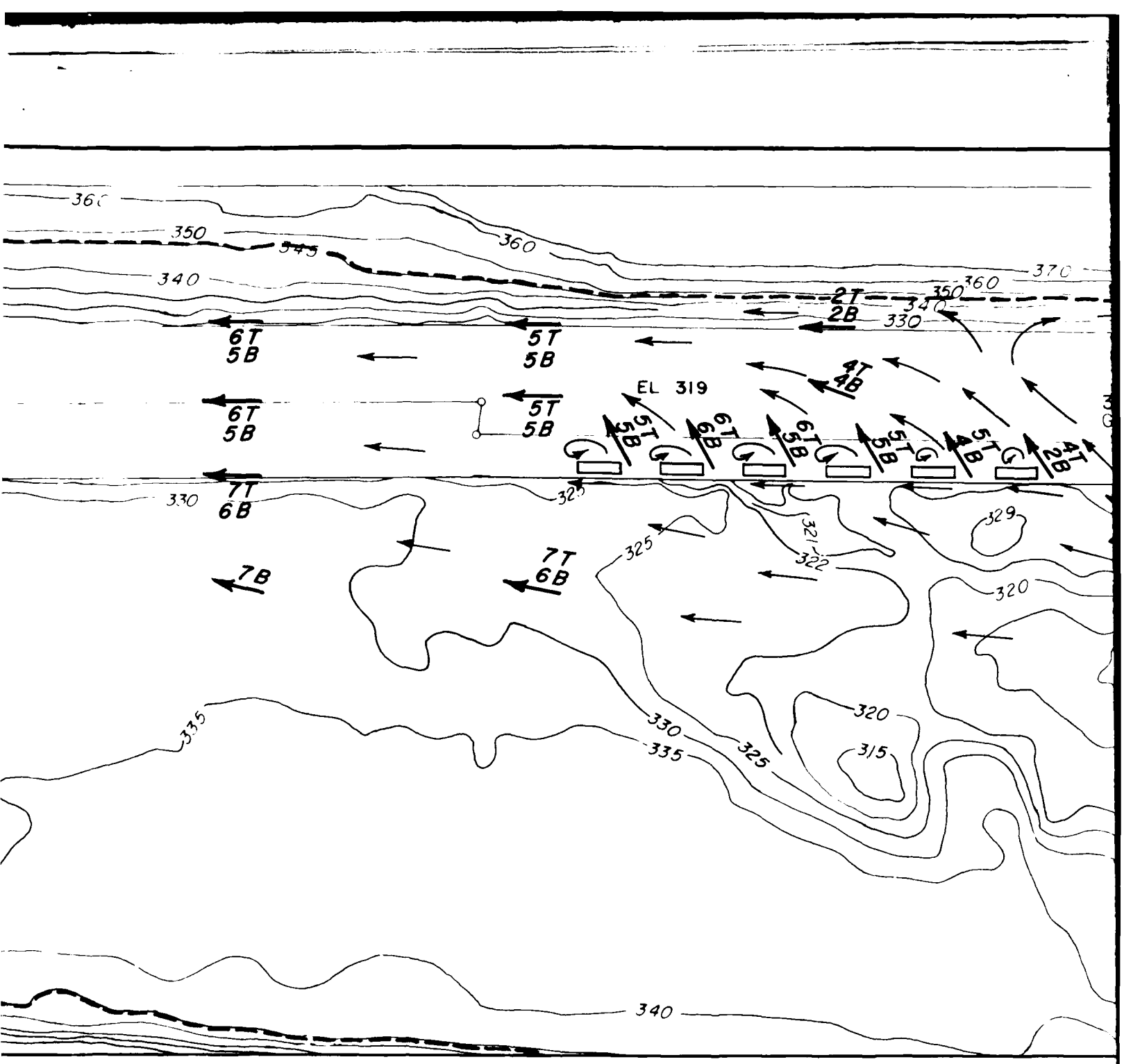
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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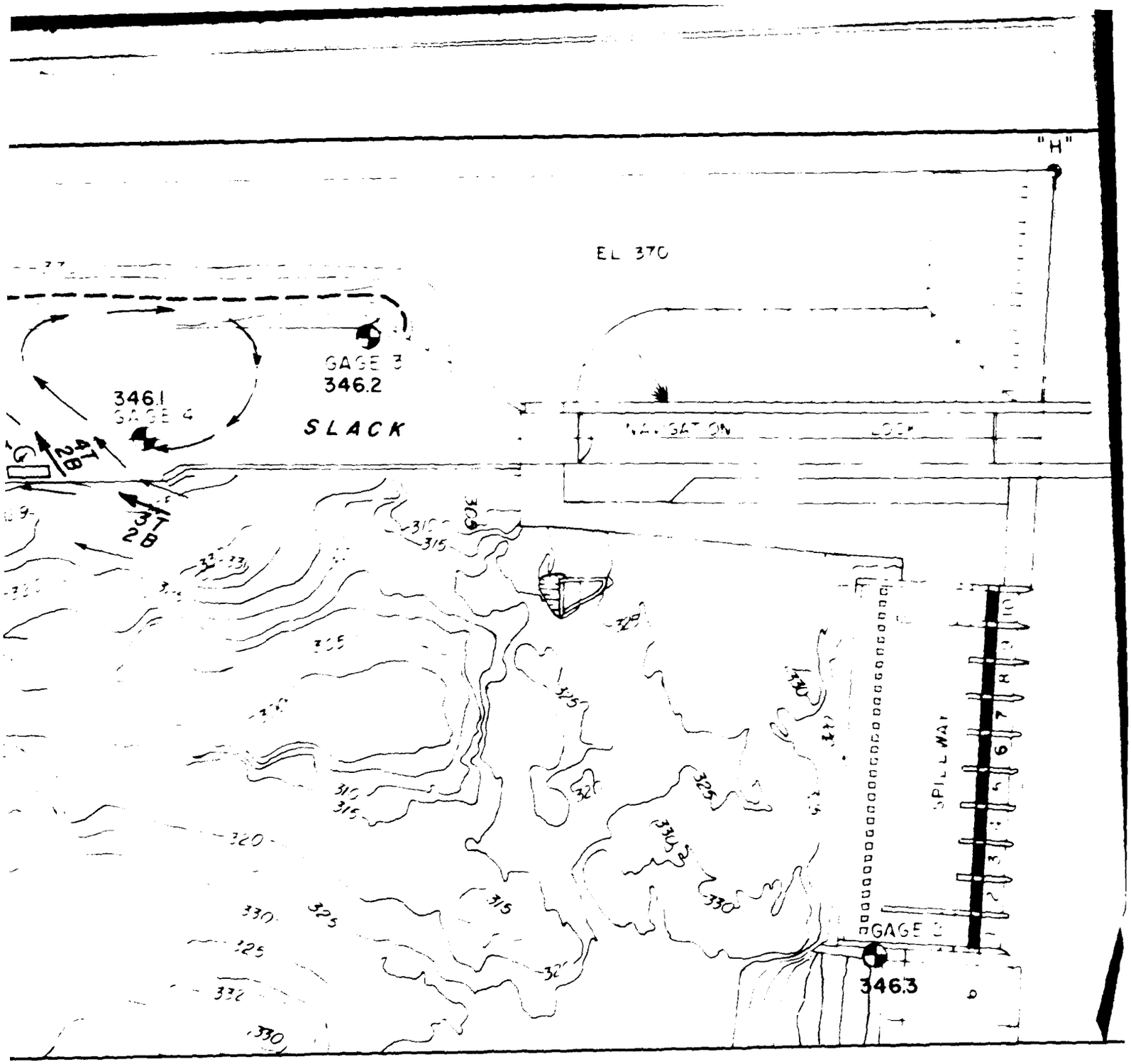
FLOW DISTRIB

SPILLWAY BAYS

POWERHOUSE UNITS

POWERHOUSE UNITS



SIX 70-FT WALLS WITH

OW DISTRIBUTION

	CLOSED
TS	43 300 CFS
ITS	56 700 CFS

FLOW COND

RIVER DISCHARGE I
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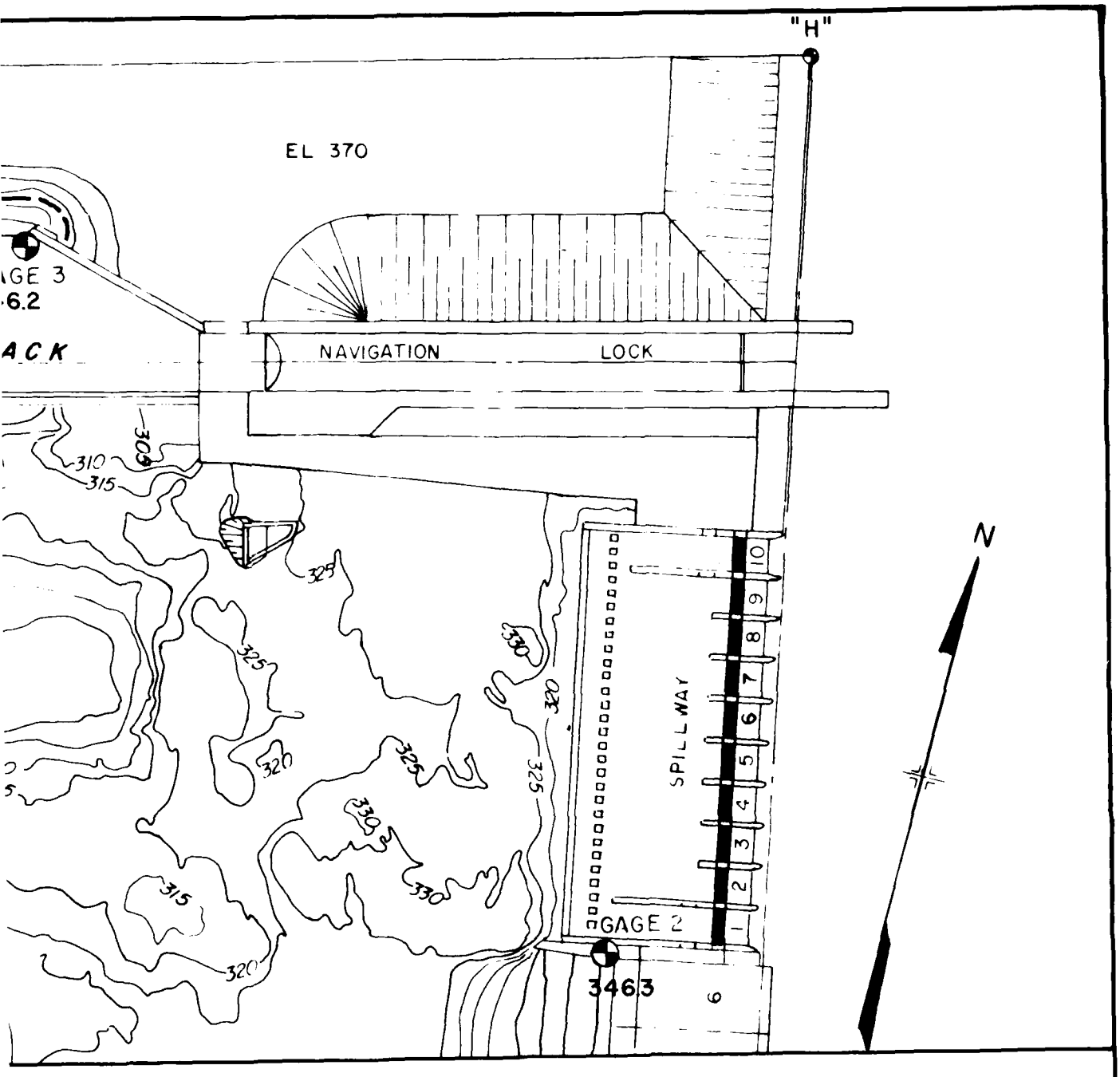
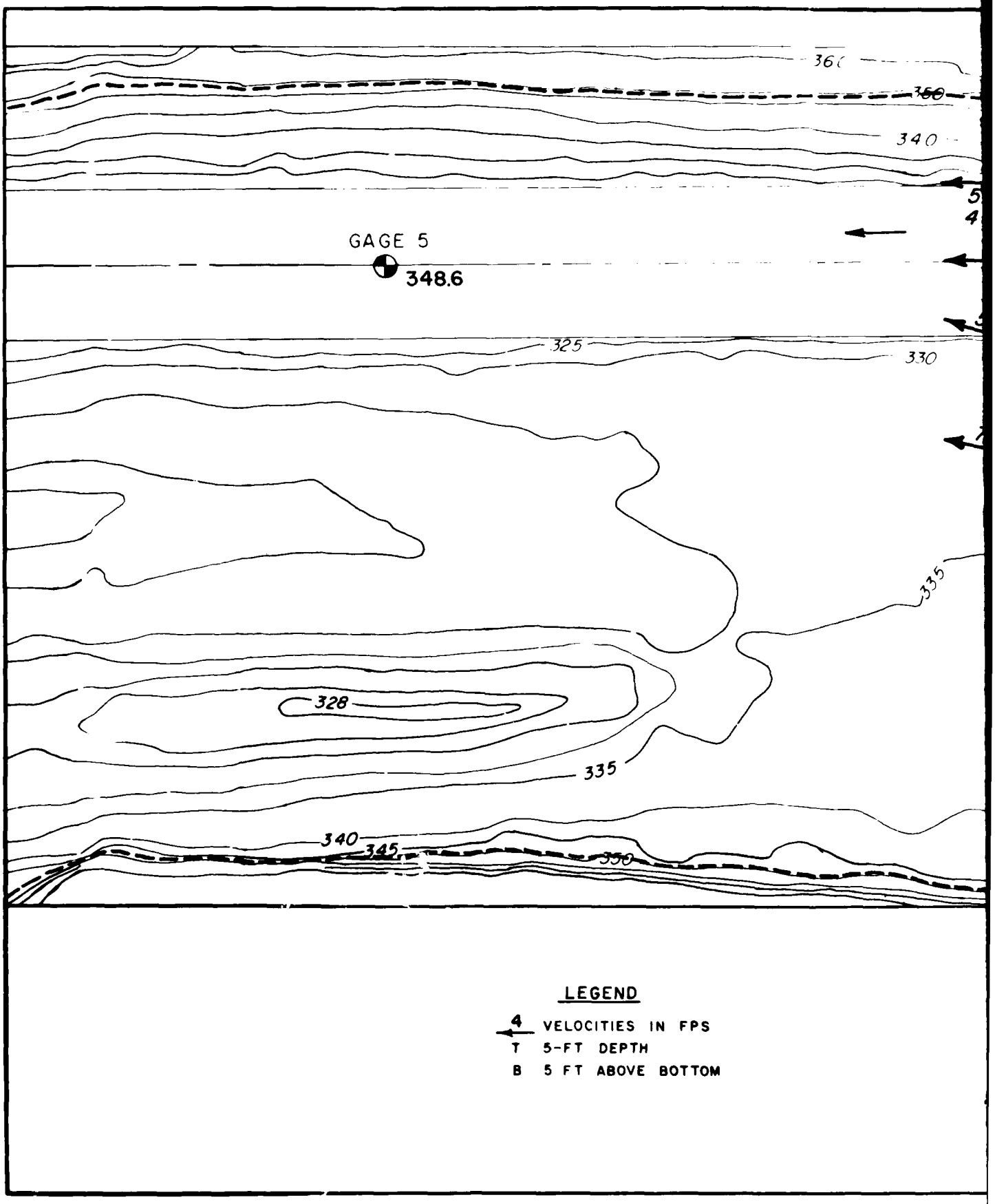


SIX 70-FT WALLS WITH 70-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 28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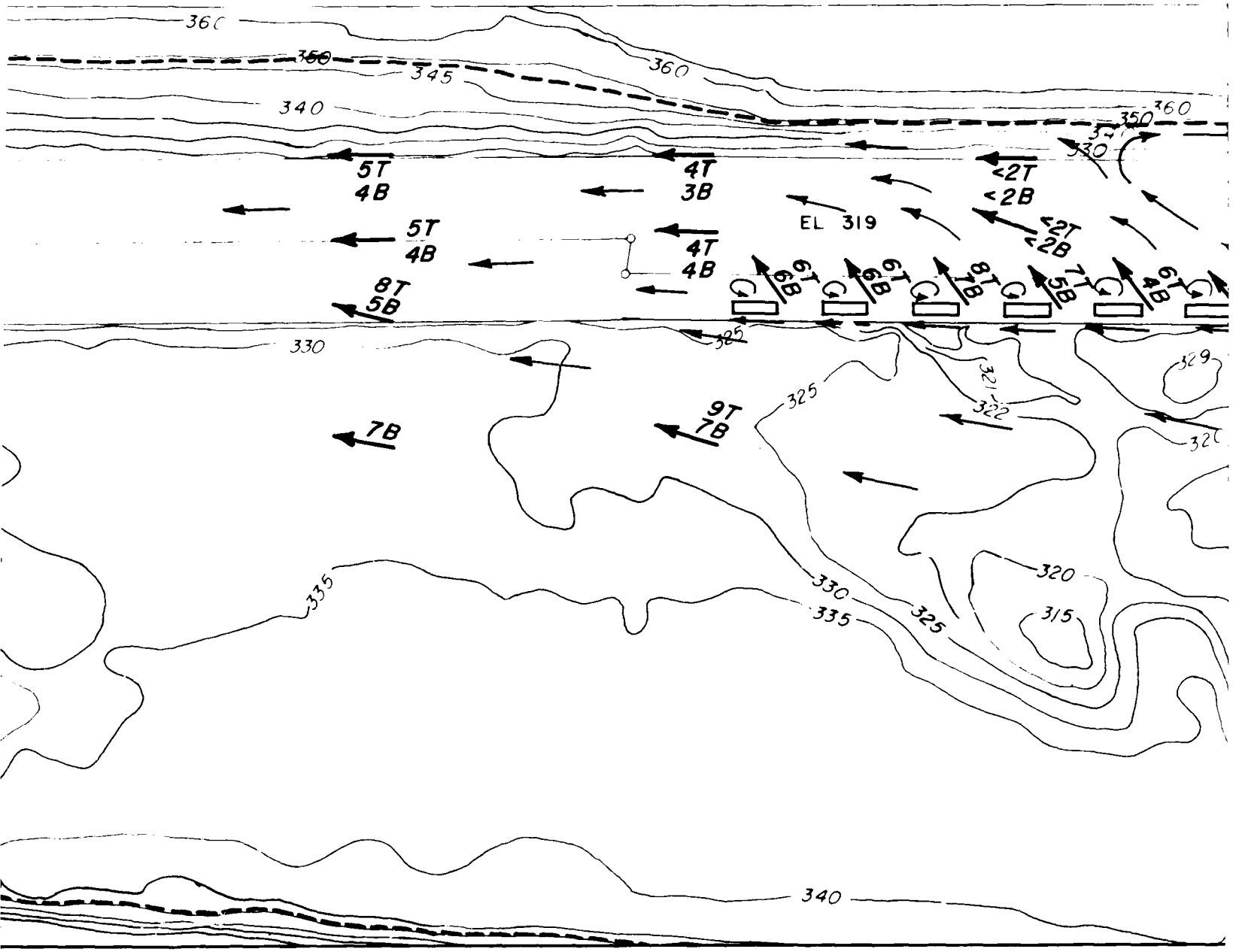
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

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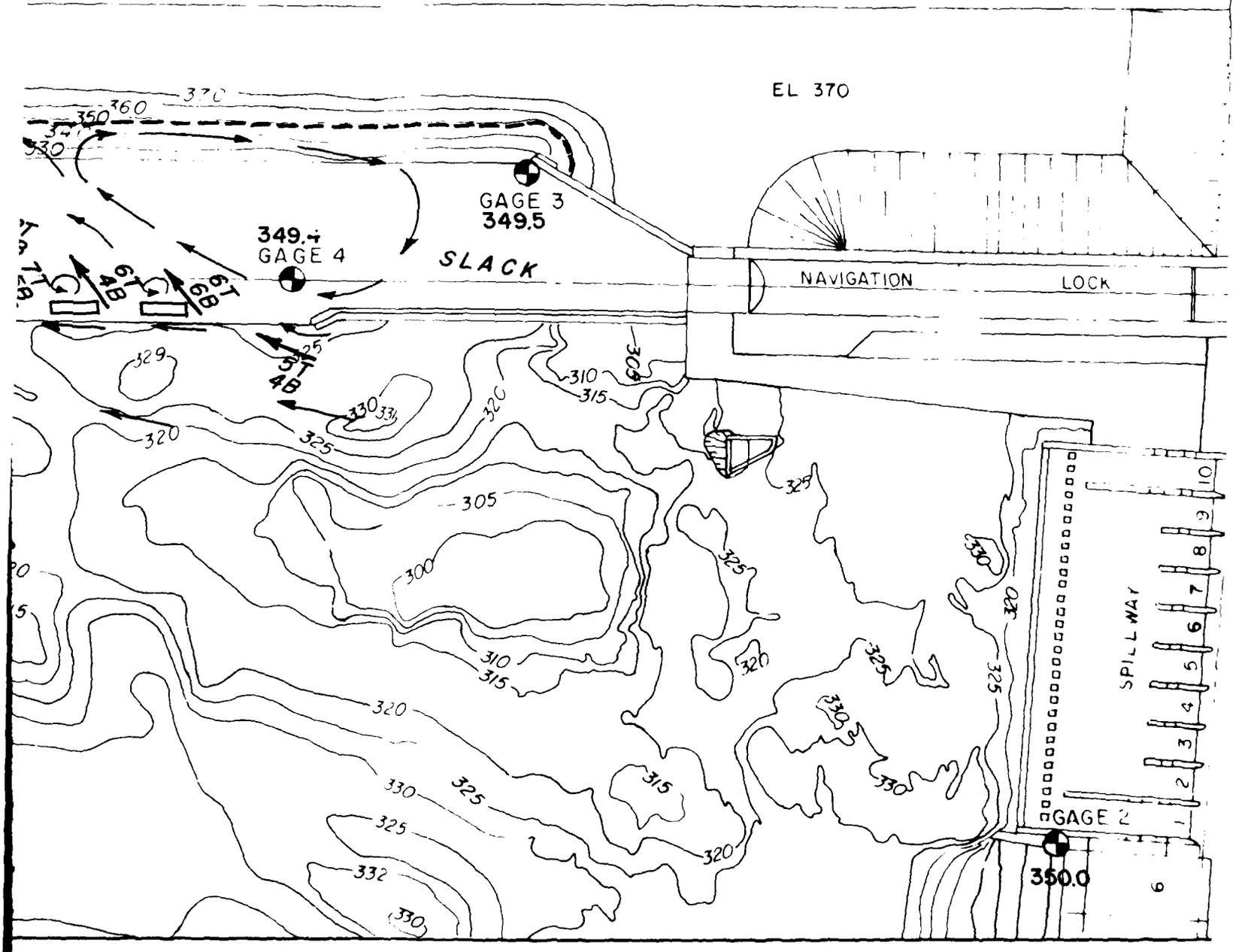
FLOW

SPILLWAY BAYS 1 TO
POWERHOUSE UNITS
POWERHOUSE UNITS



FLOW DISTRIBUTION

LWAY BAYS 1 TO 10	50 000 CFS
ERHOUSE UNITS 1 TO 3	43 300 CFS
ERHOUSE UNITS 4 TO 6	56 700 CFS

SIX 70-FT WALI

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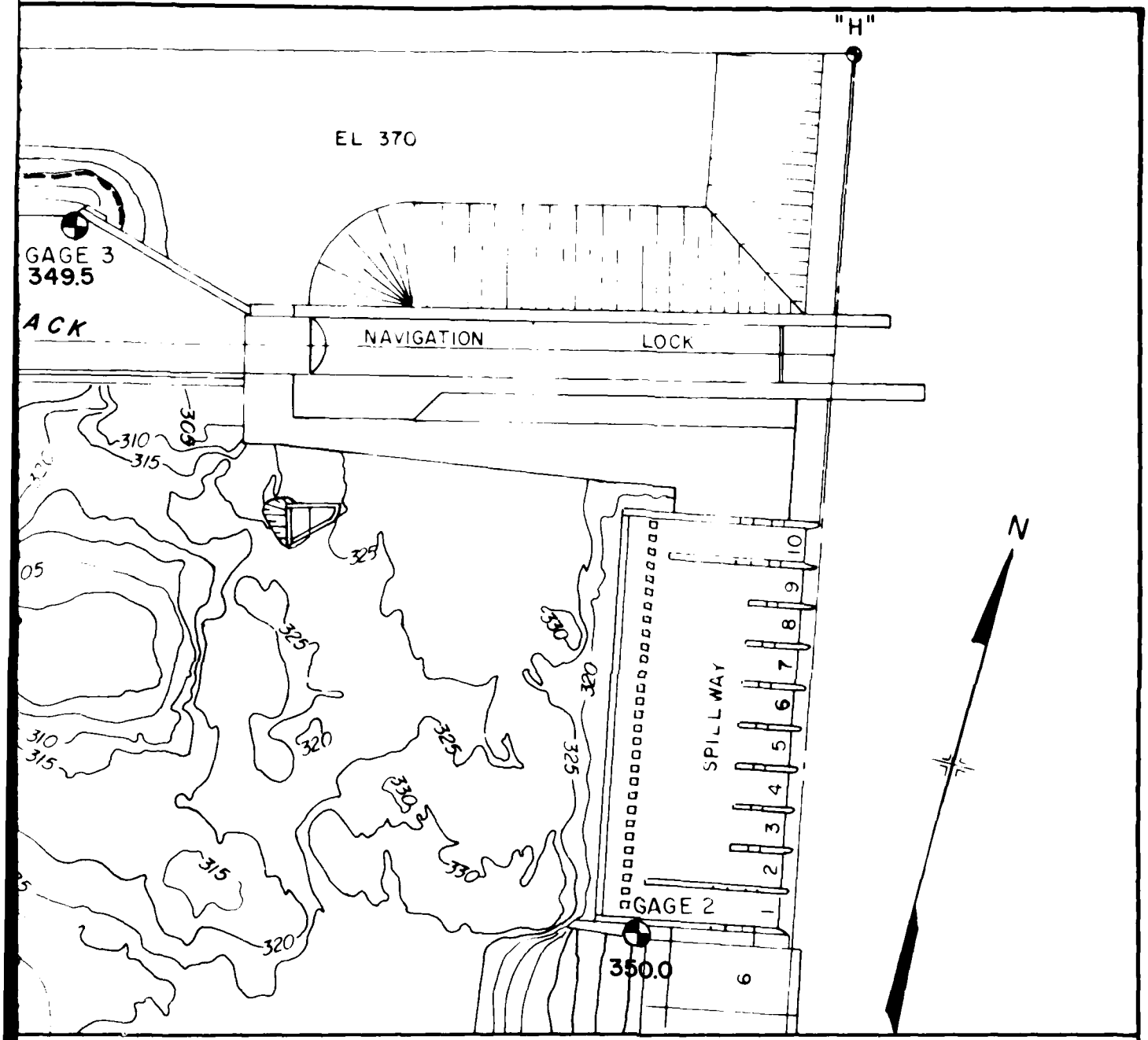
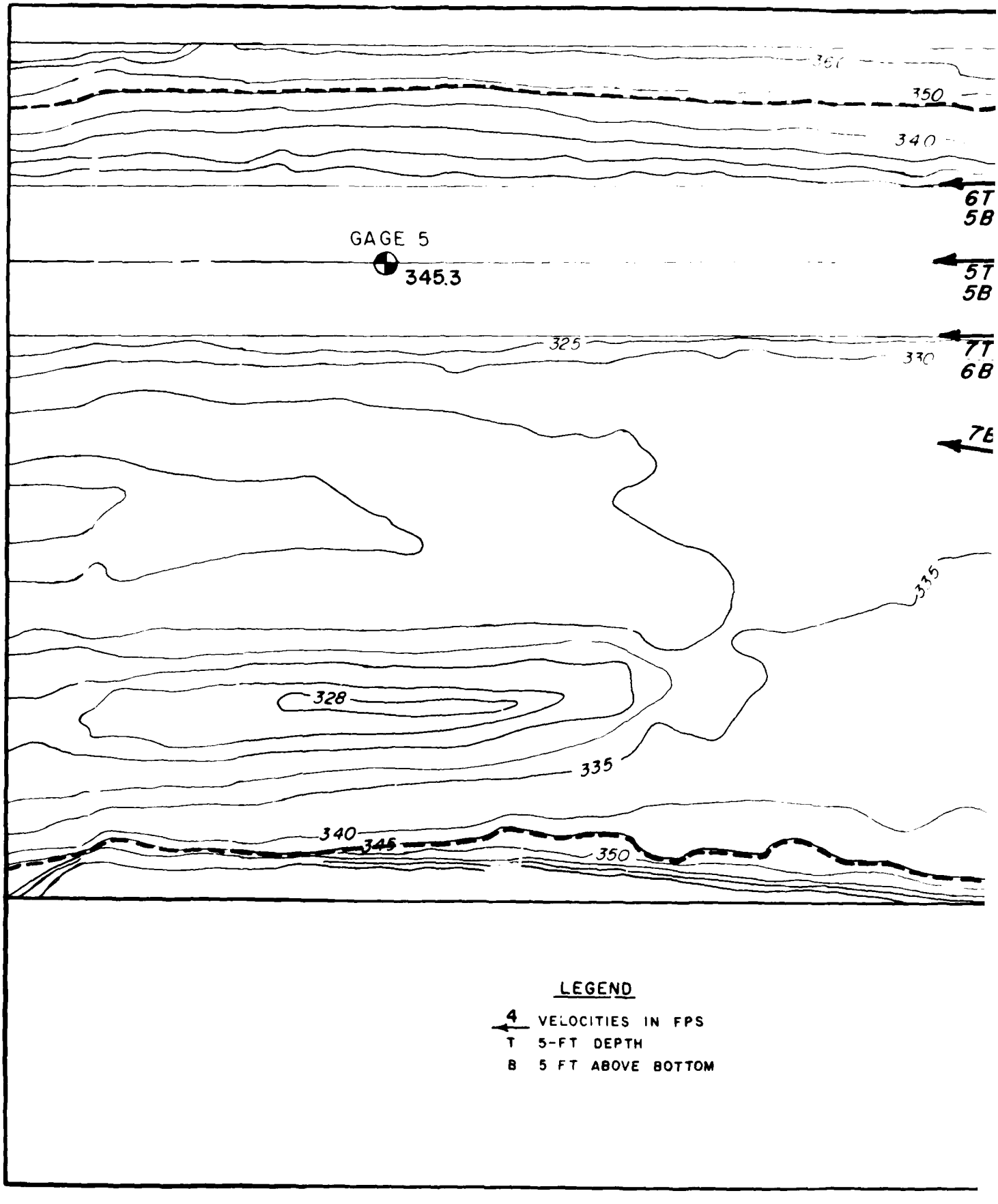


SIX 70-FT WALLS WITH 70-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 29



LEGEND

4 ← VELOCITIES IN FPS

T 5-FT DEPTH

B 5 FT ABOVE BOTTOM

SCALE

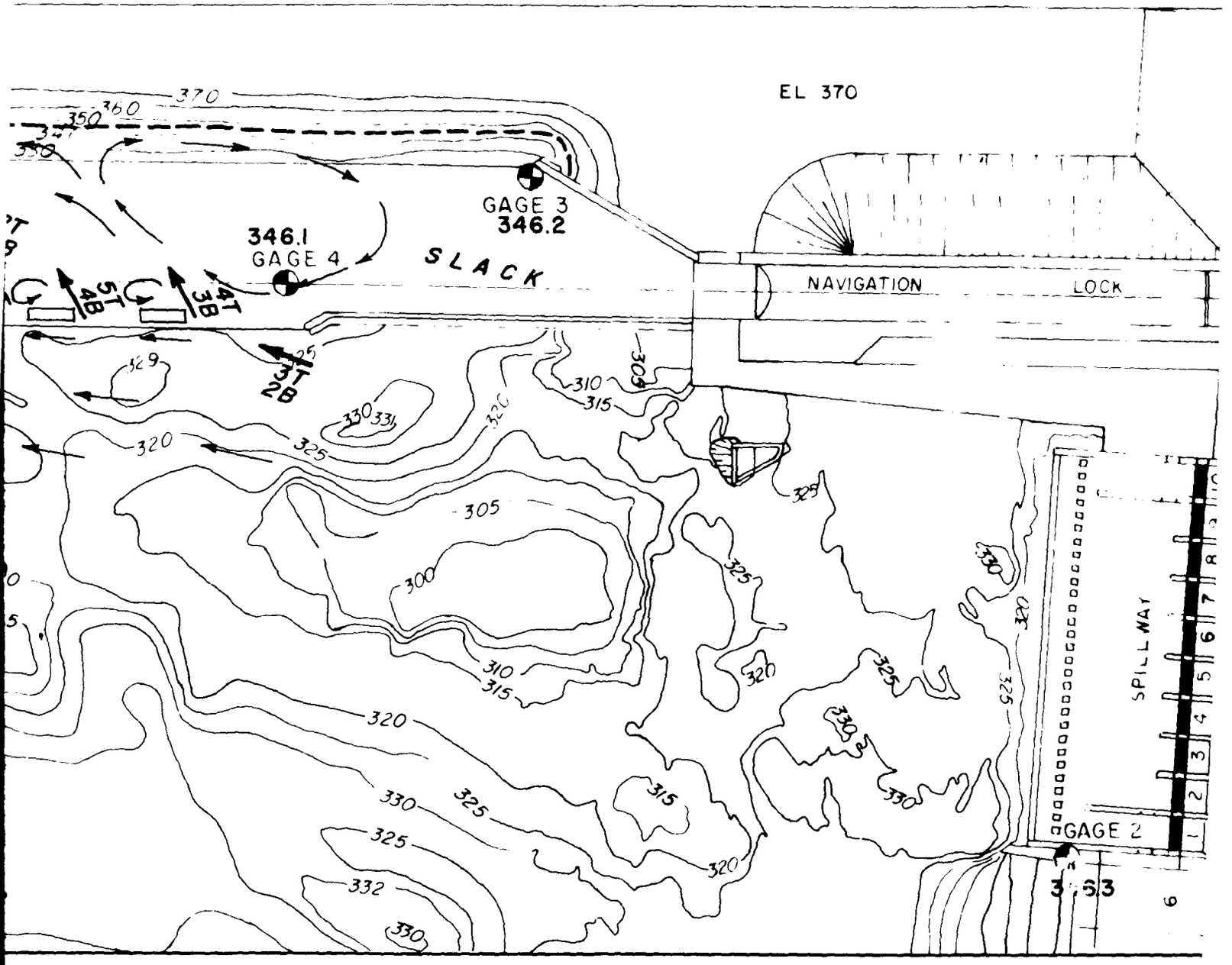
0 100 200 300 400 500 FT

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

LWAY BAYS 1 TO 10	CLOSED
ERHOUSE UNITS 1 TO 3	43 300 CFS
ERHOUSE UNITS 4 TO 6	56 700 CFS

FIVE 70-FT WA

FI

RIVER

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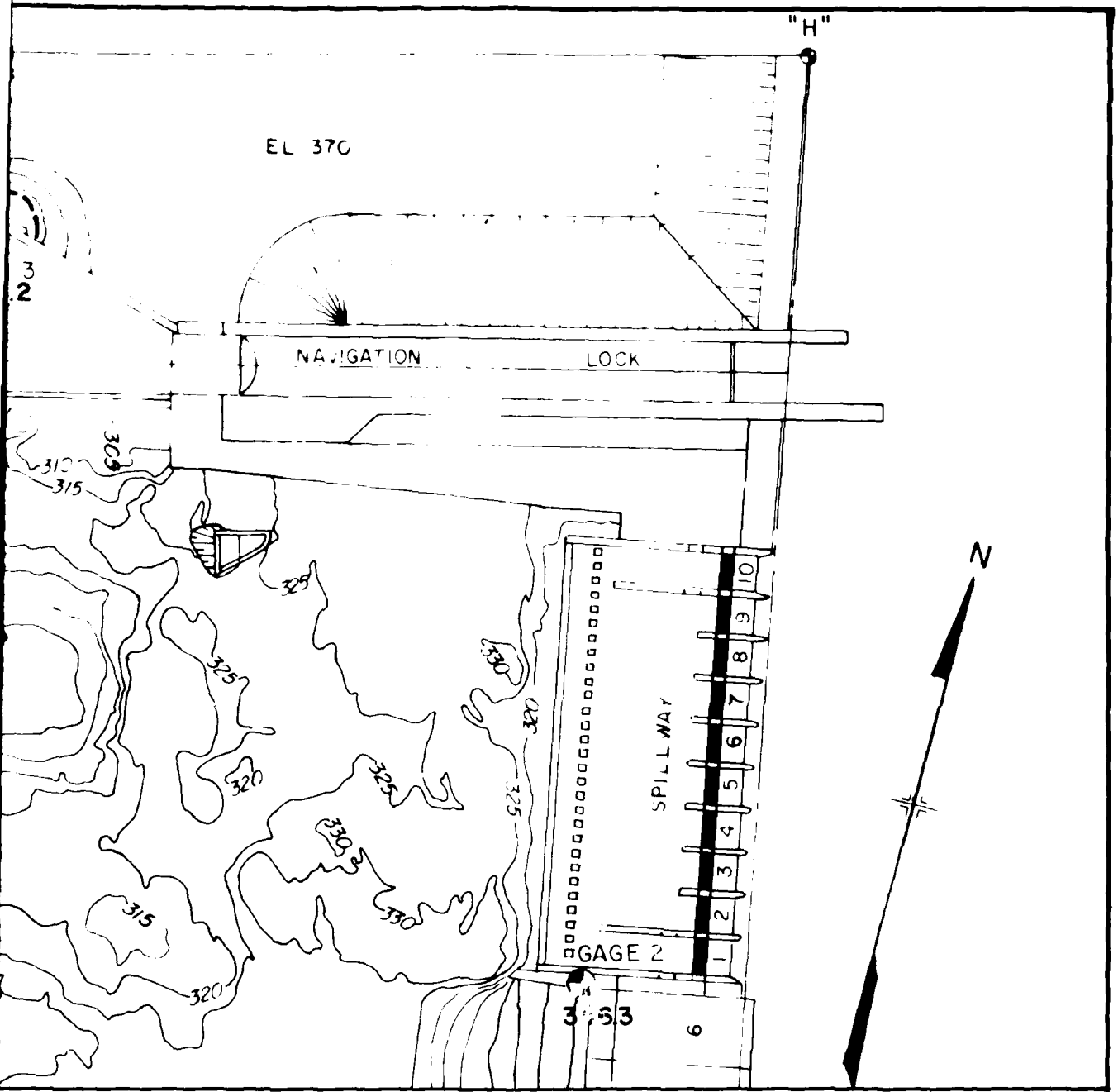
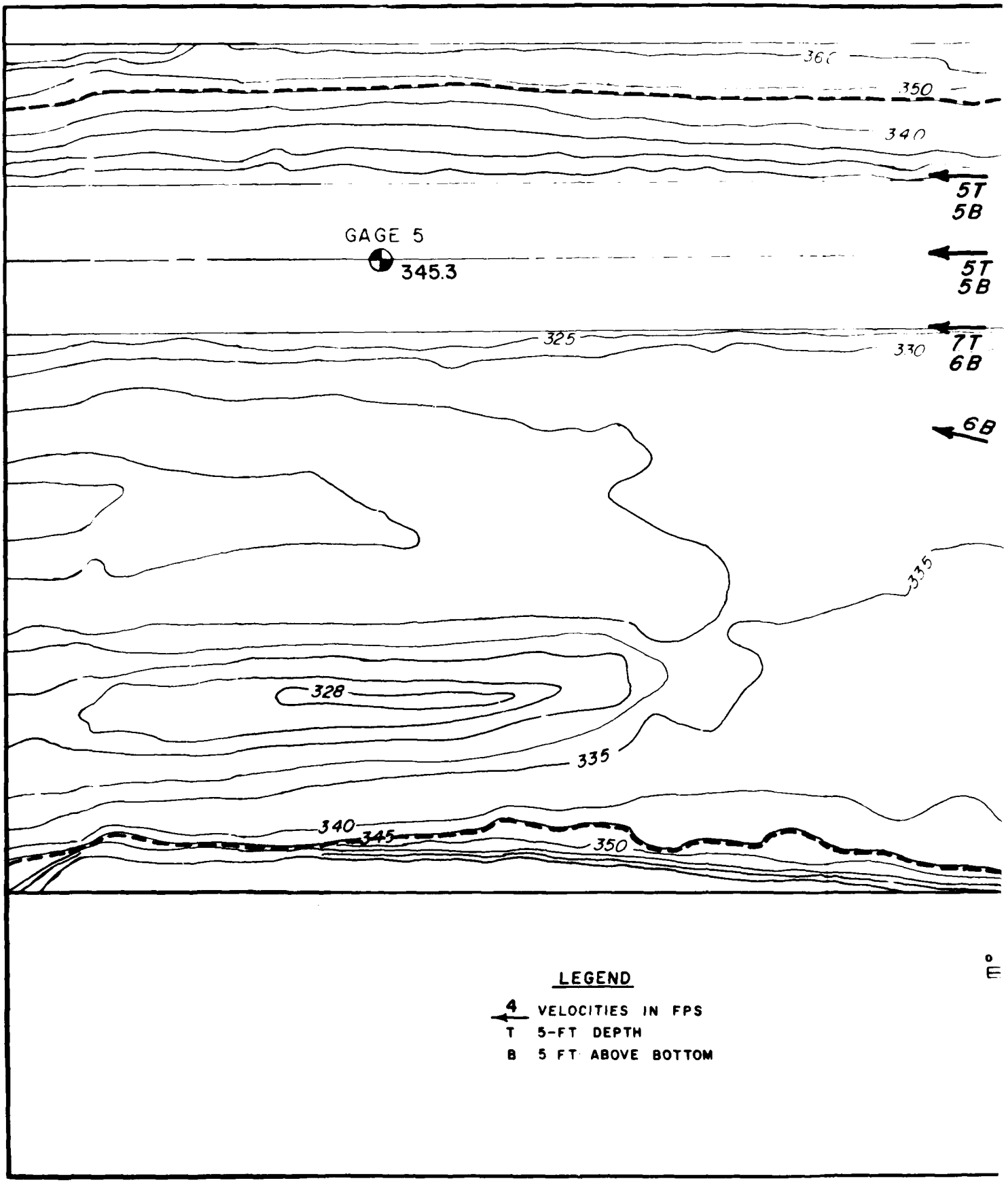


FIVE 70-FT WALLS WITH 100-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100000 CFS
McNARY POOL EL 335

PLATE 30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LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM

SCALE

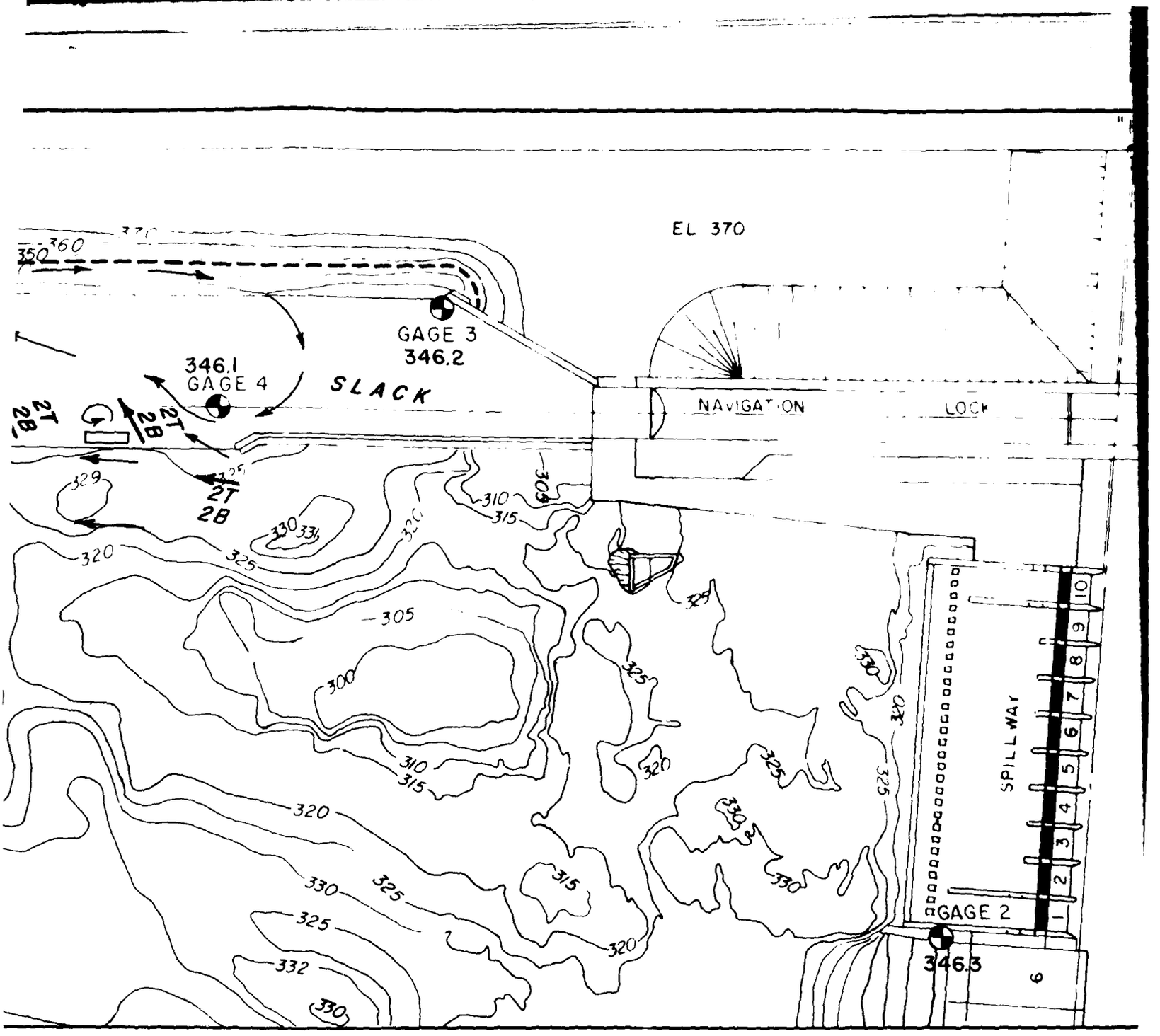
0 100 200 300 400 500 FT

FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



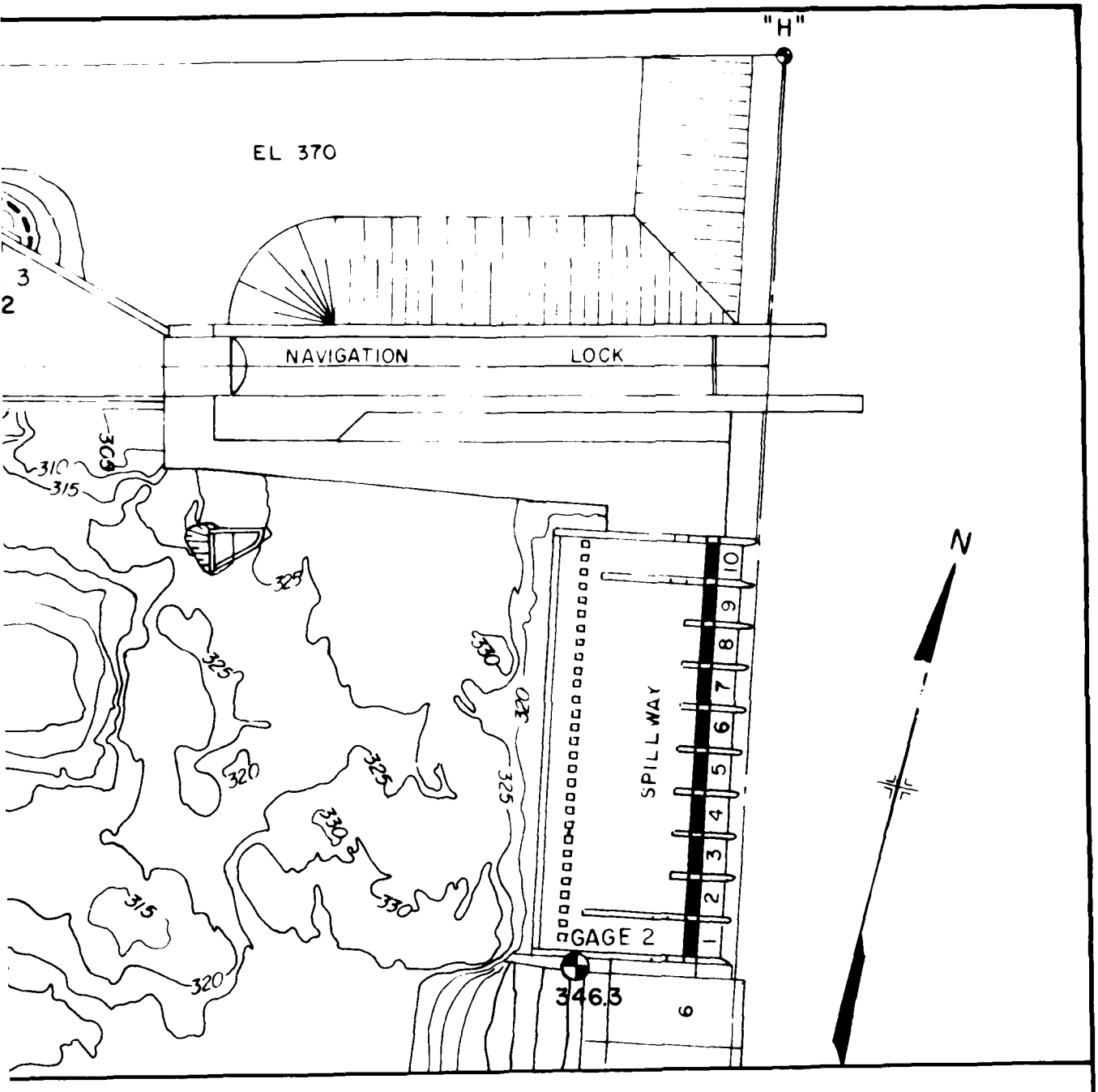
FOUR 70-FT WALLS W

FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
USE UNITS 1 TO 3	43 300 CFS
USE UNITS 4 TO 6	56 700 CFS

FLOW C

RIVER DISCH
McNARY

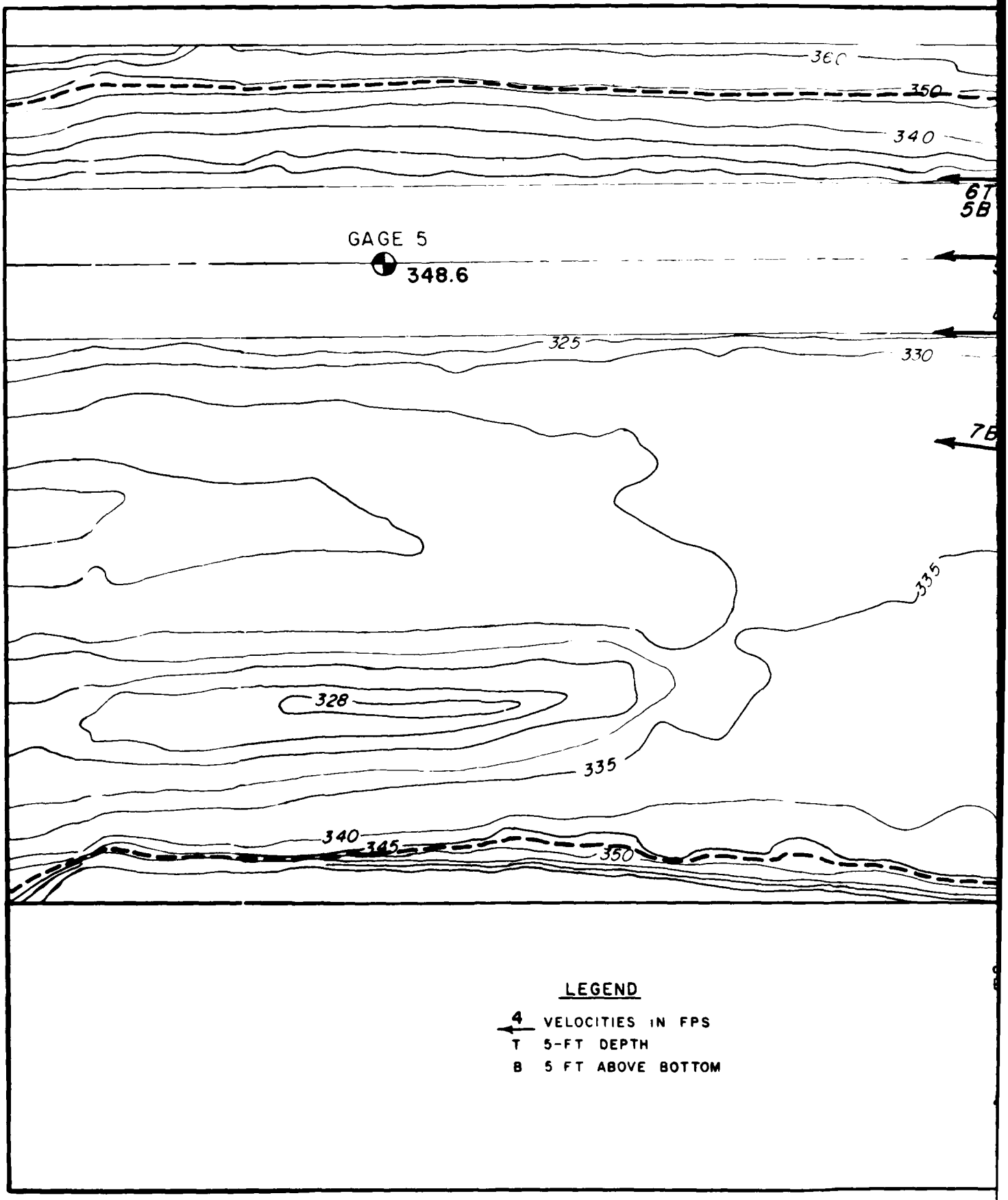


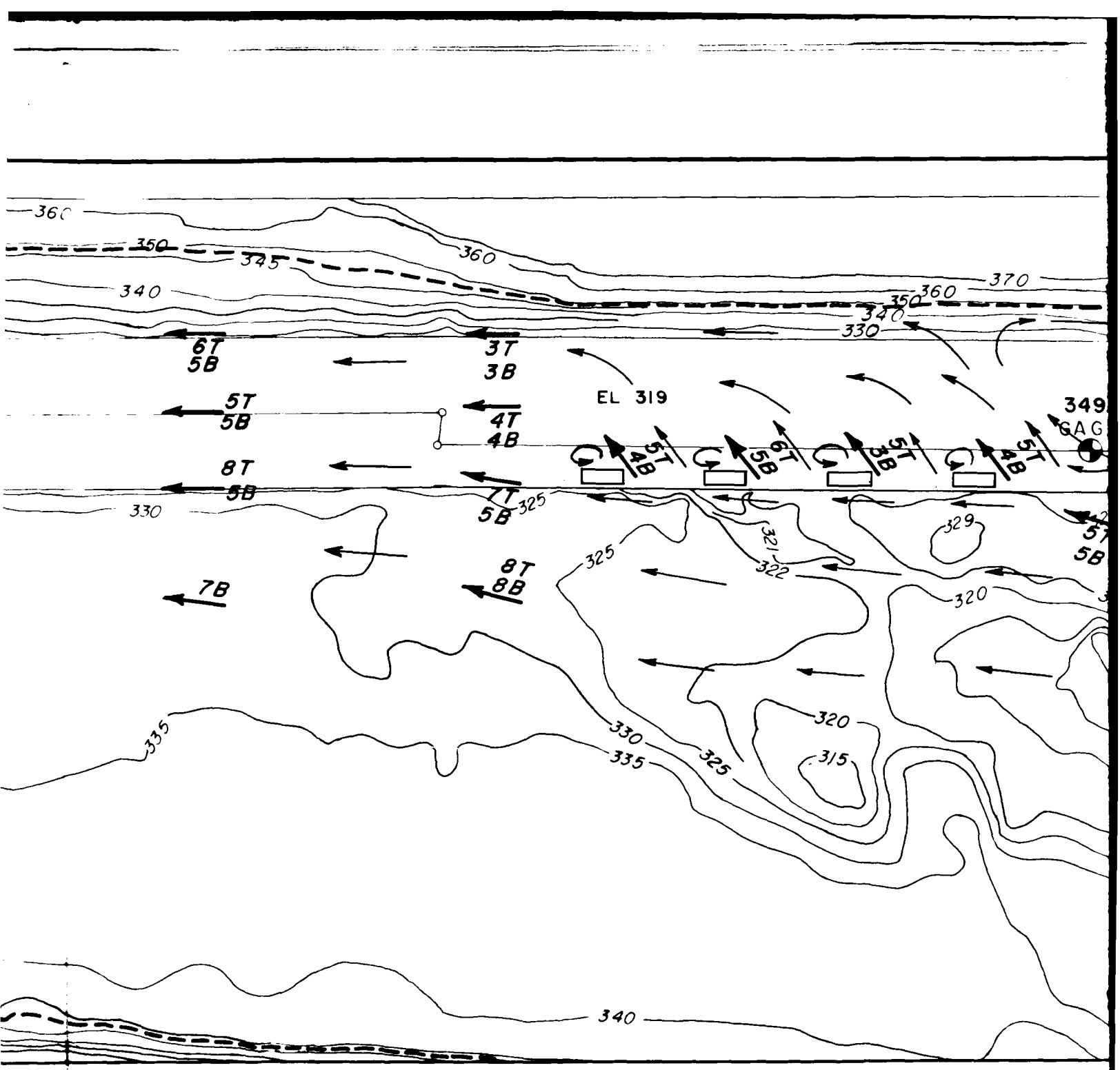
FOUR 70-FT WALLS WITH 140-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 31


350
340
6T
5B
GAGE 5
348.6
325
330
7B
335
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

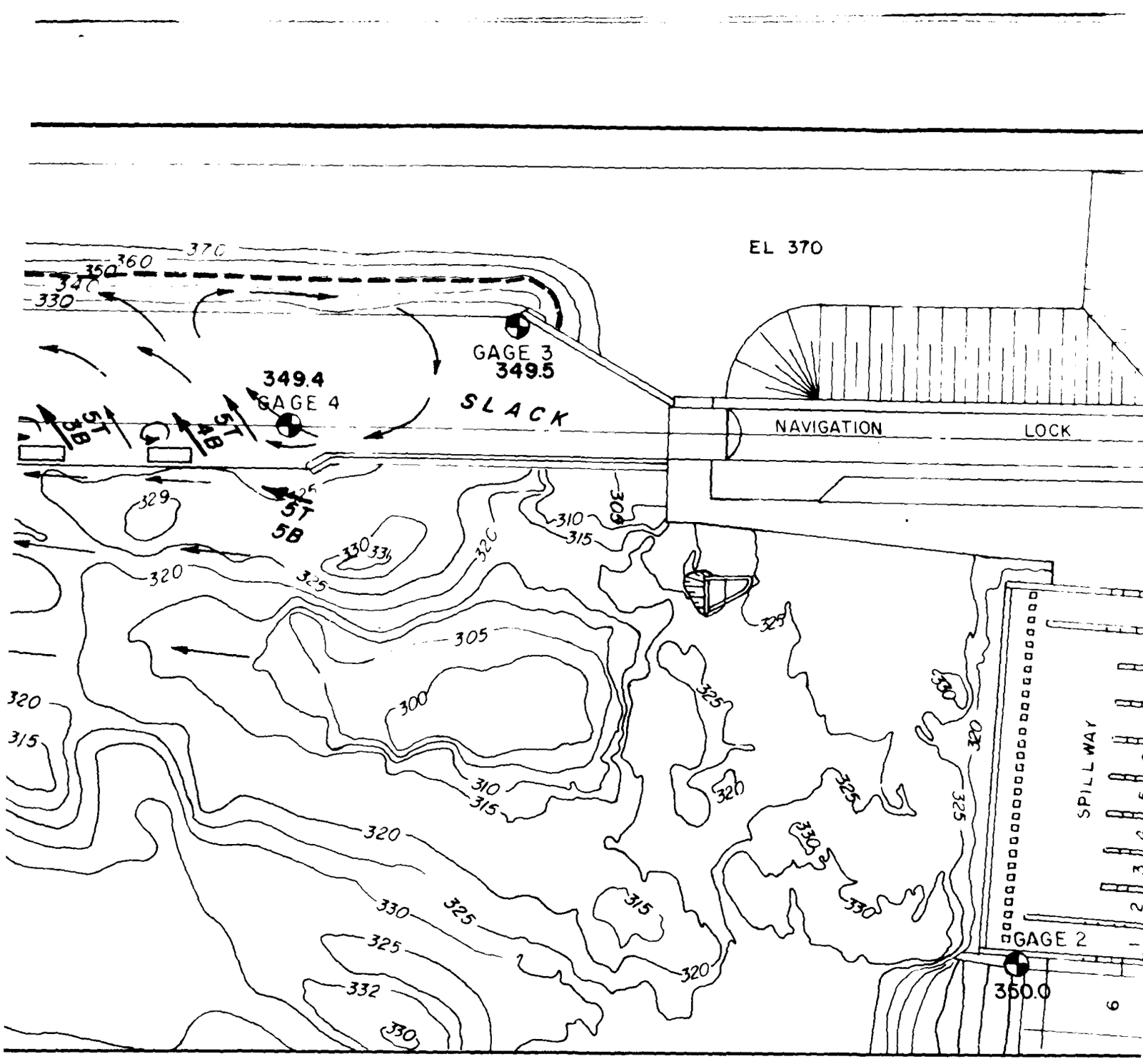
0 100 200 300 400 500 FT

FLOW DISTRIBUTIO

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

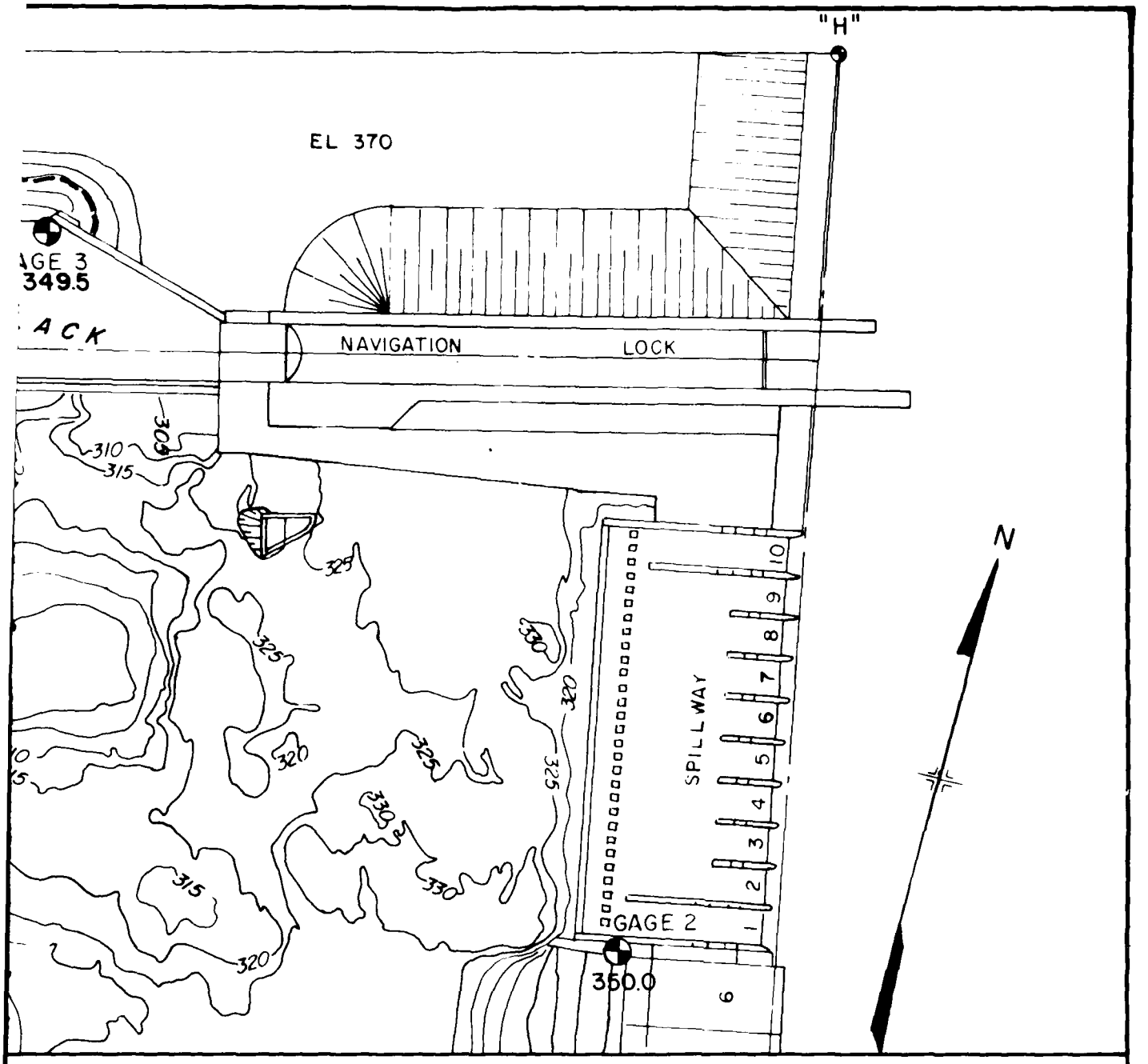
PILLWAY BAYS 1 TO 10	50 000 CFS
OWERHOUSE UNITS 1 TO 3	43 300 CFS
OWERHOUSE UNITS 4 TO 6	56 700 CFS

FOUR 70-FT W

F

RIVER

MC

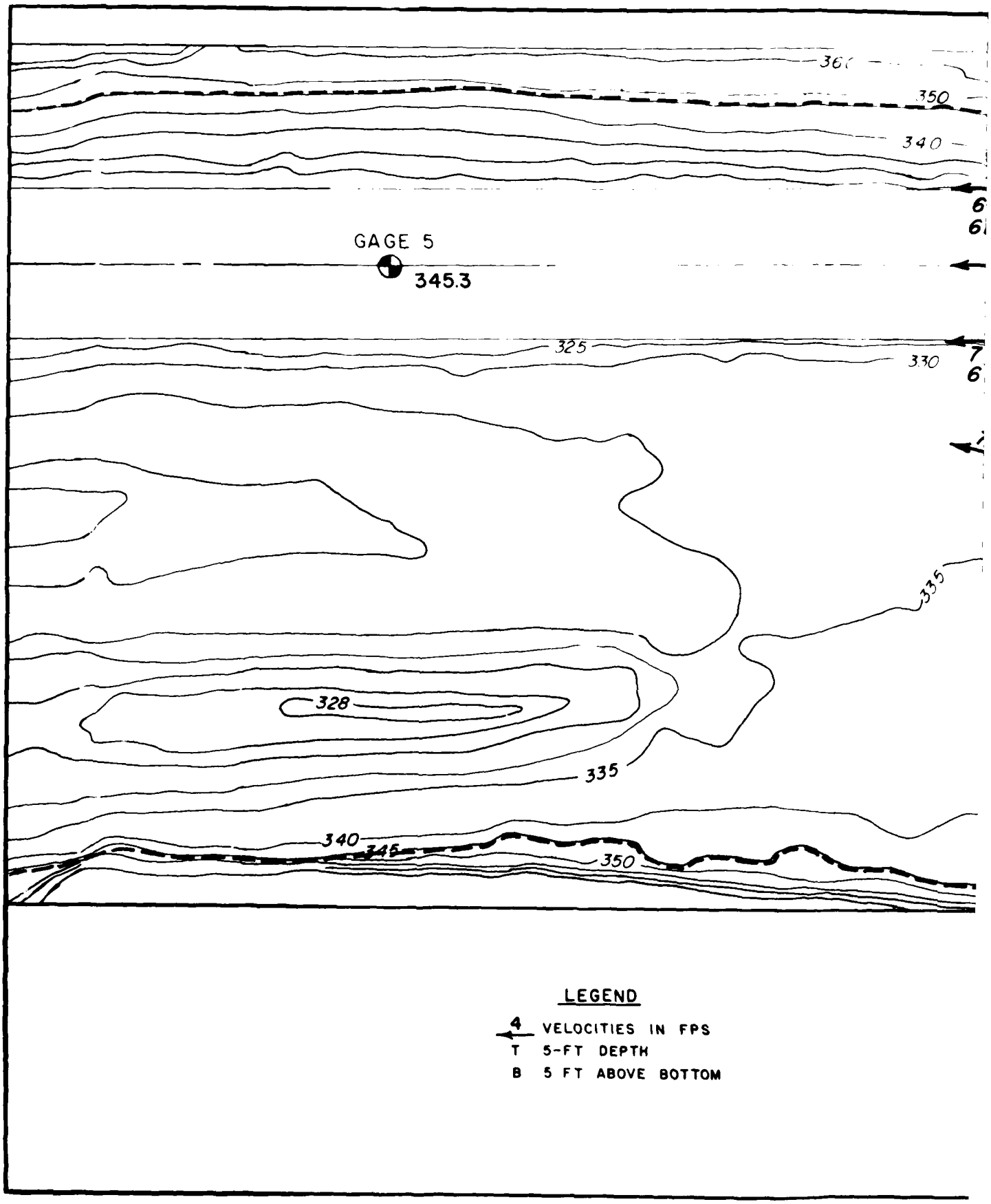


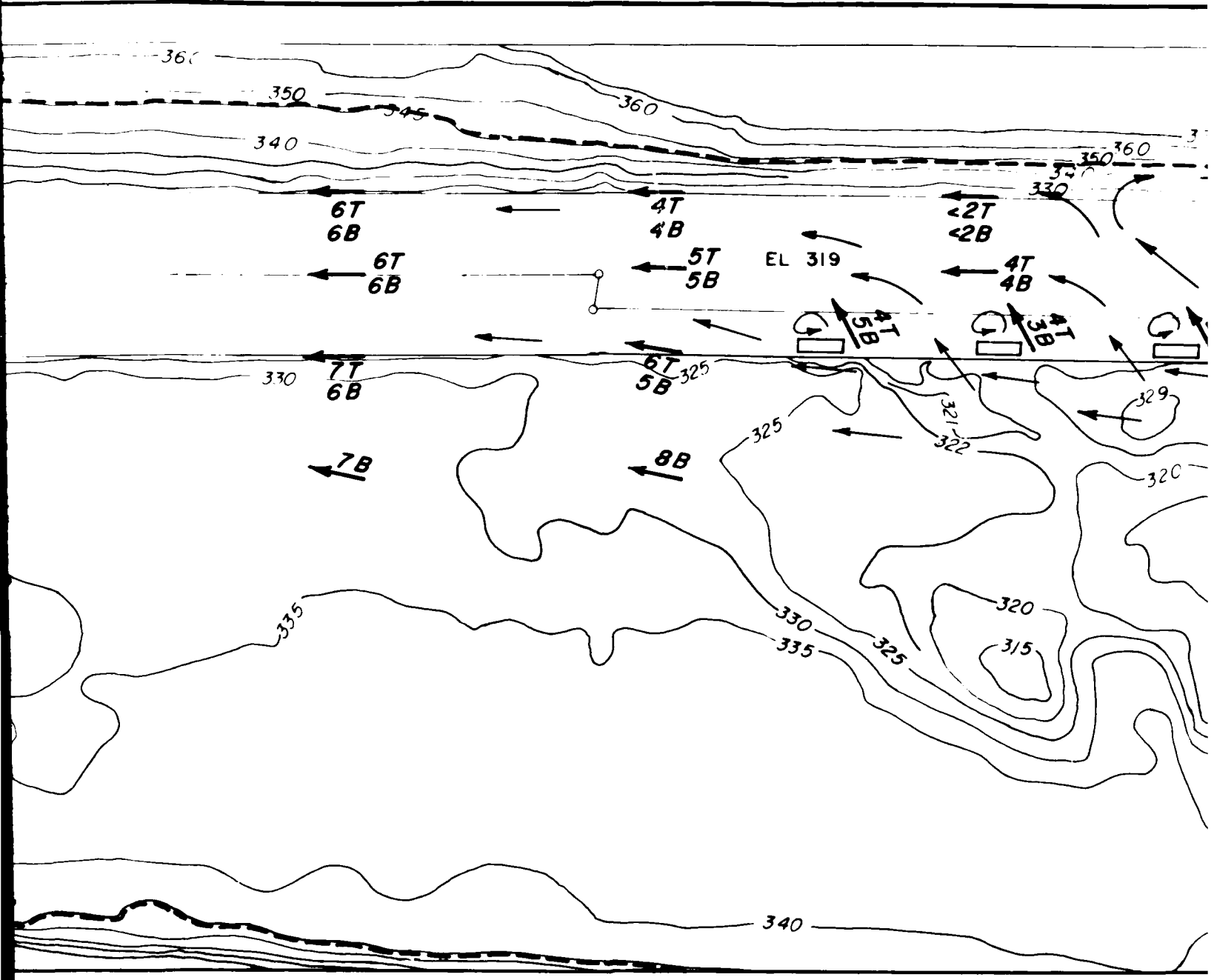
FOUR 70-FT WALLS WITH 140-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 32


GAGE 5
345.3
325
330
335
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

0 100 200 300 400 500 FT

FPS

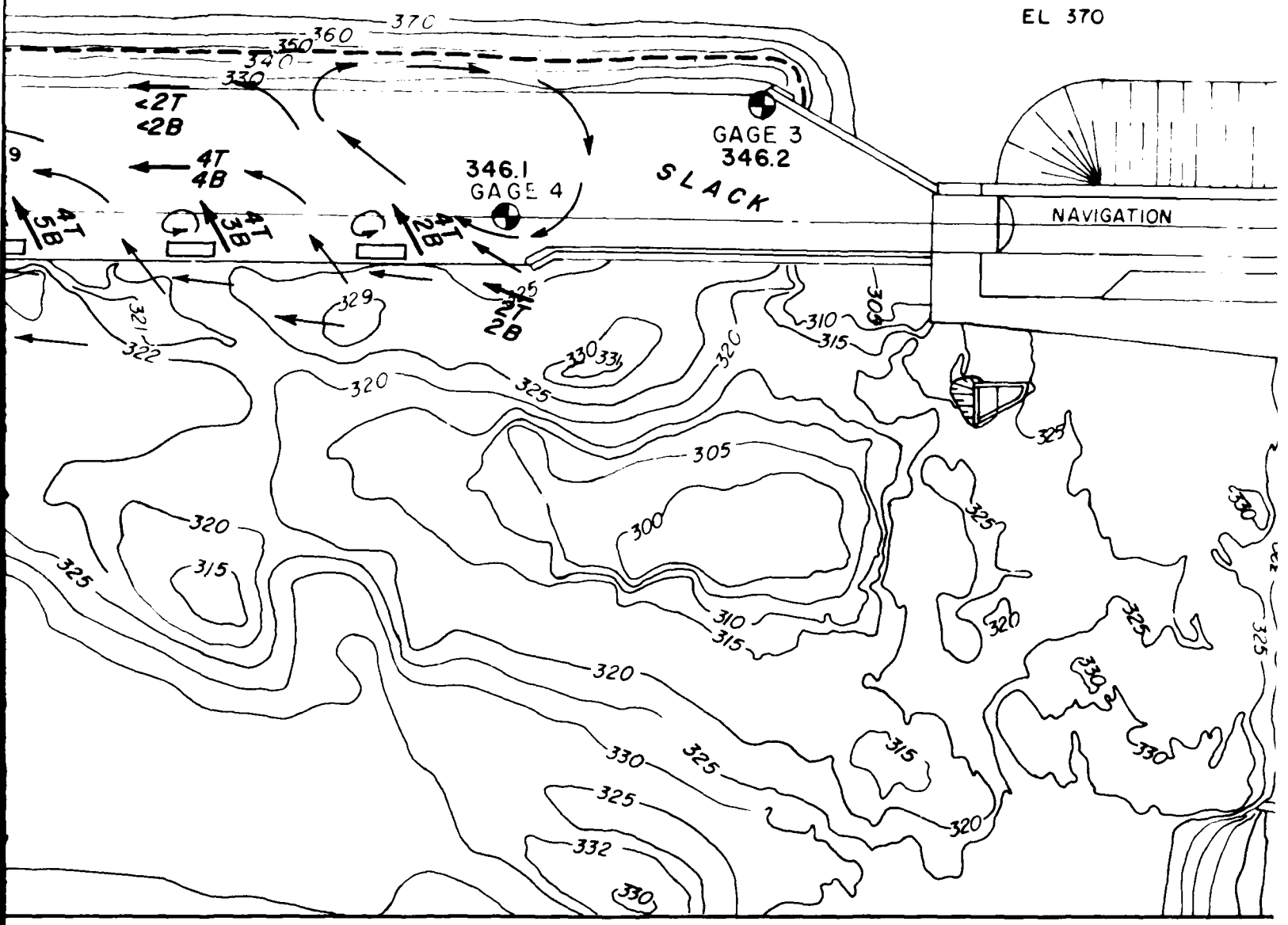
TTOM

FLOW DI

SPILLWAY BAYS 1 TO 10

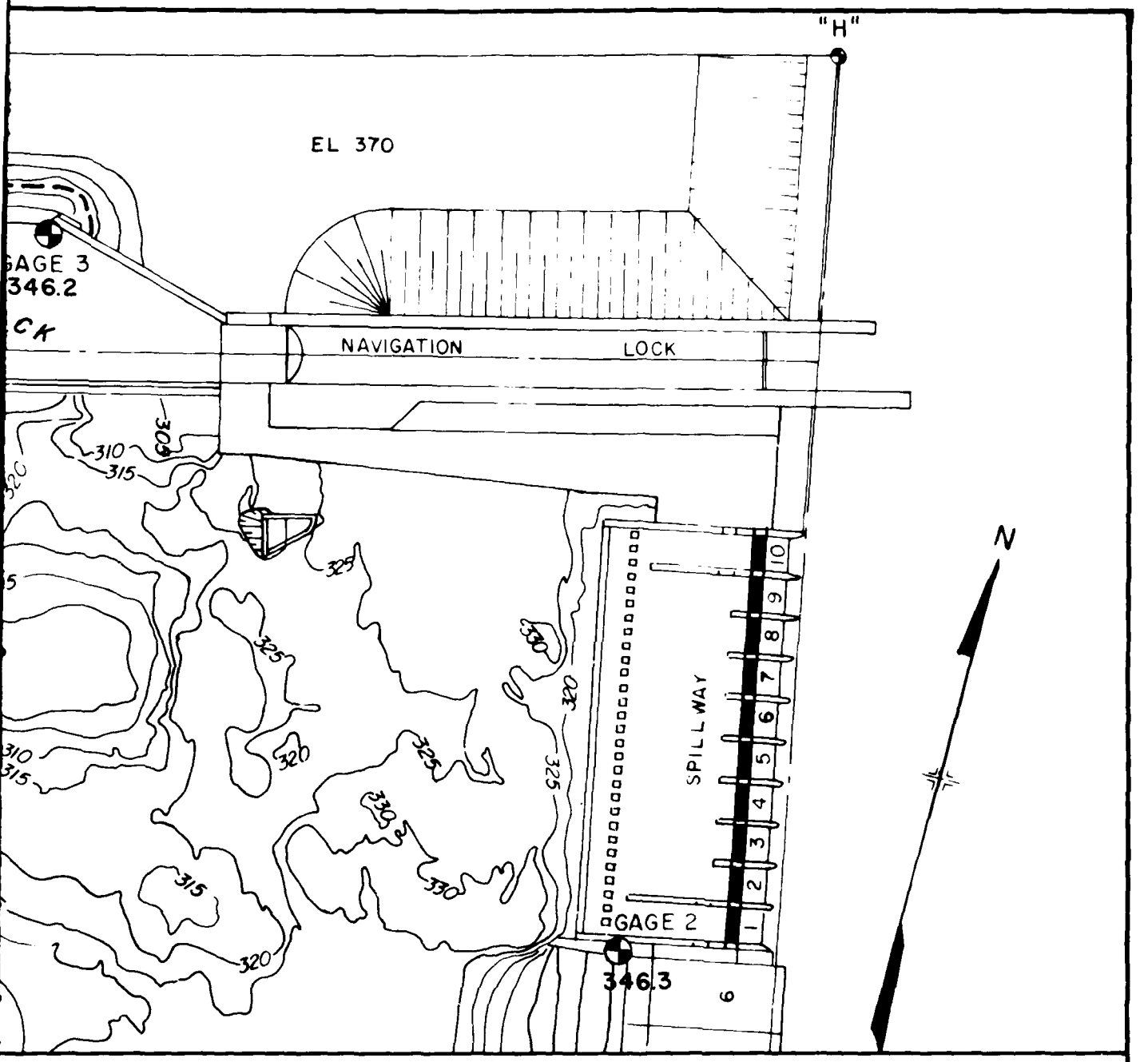
POWERHOUSE UNITS 1 TO

POWERHOUSE UNITS 4 TO



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

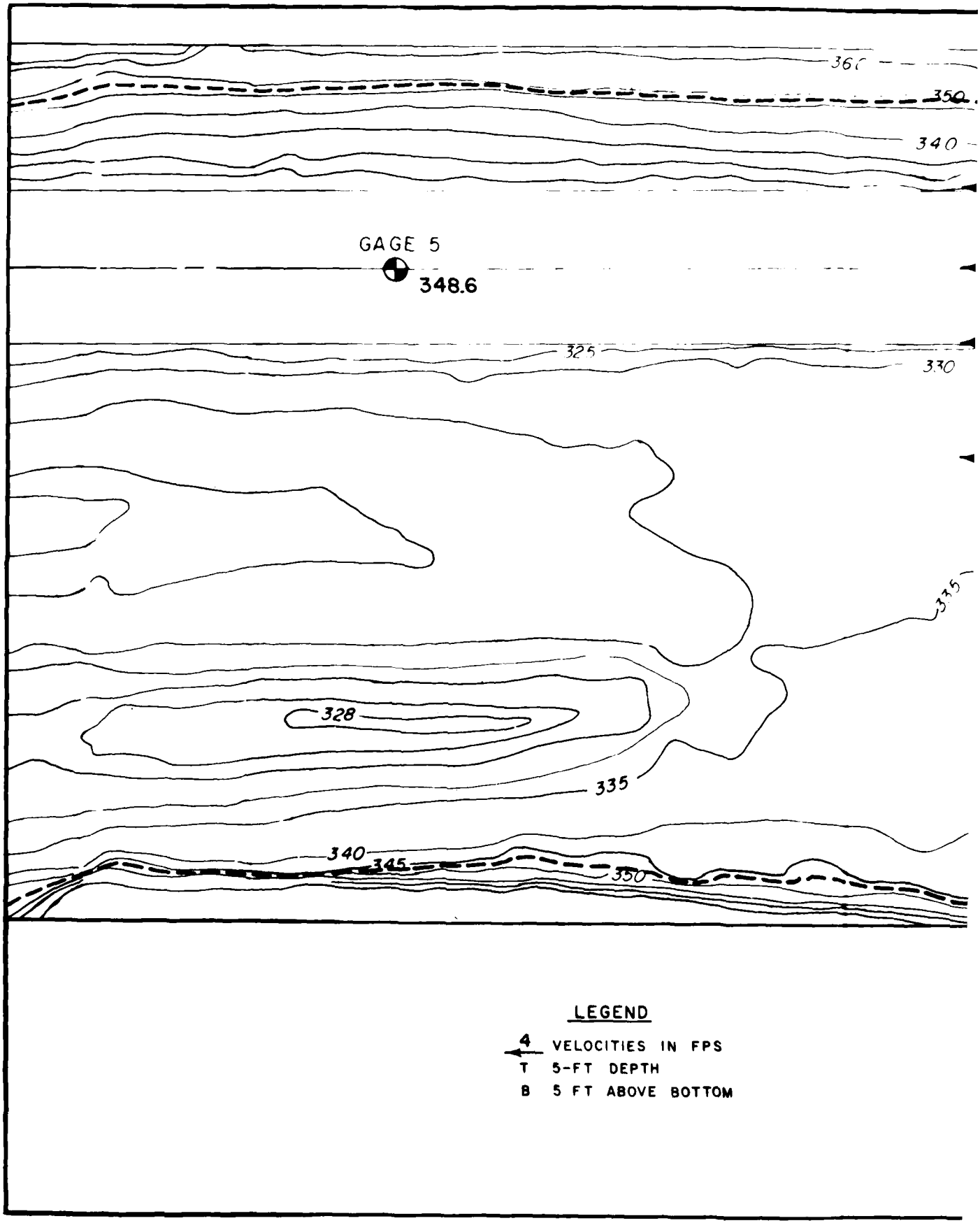


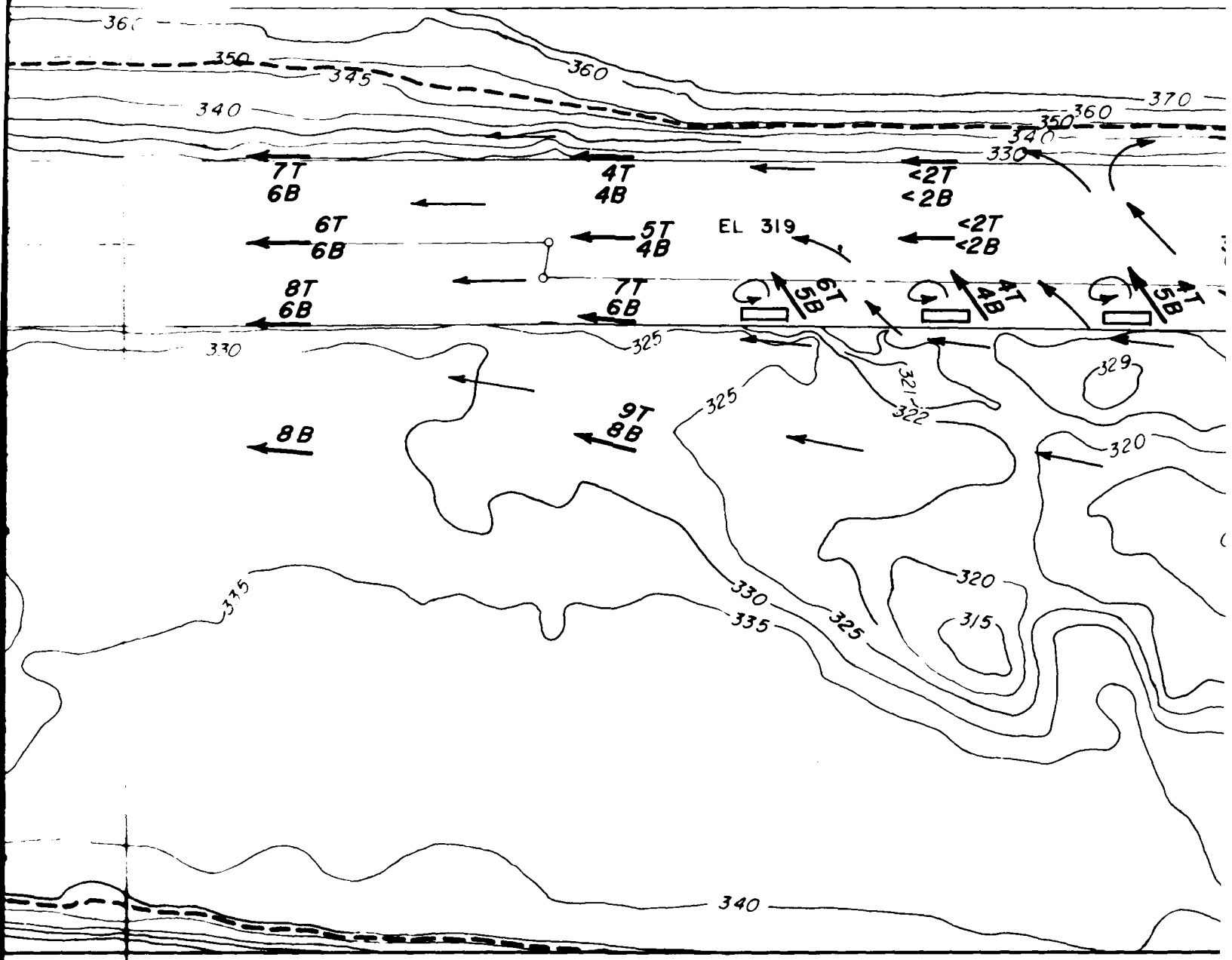
THREE 70-FT WALLS WITH 210-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

PLATE 33


360
350
340
GAGE 5
348.6
325
330
335
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

0 100 200 300 400 500 FT

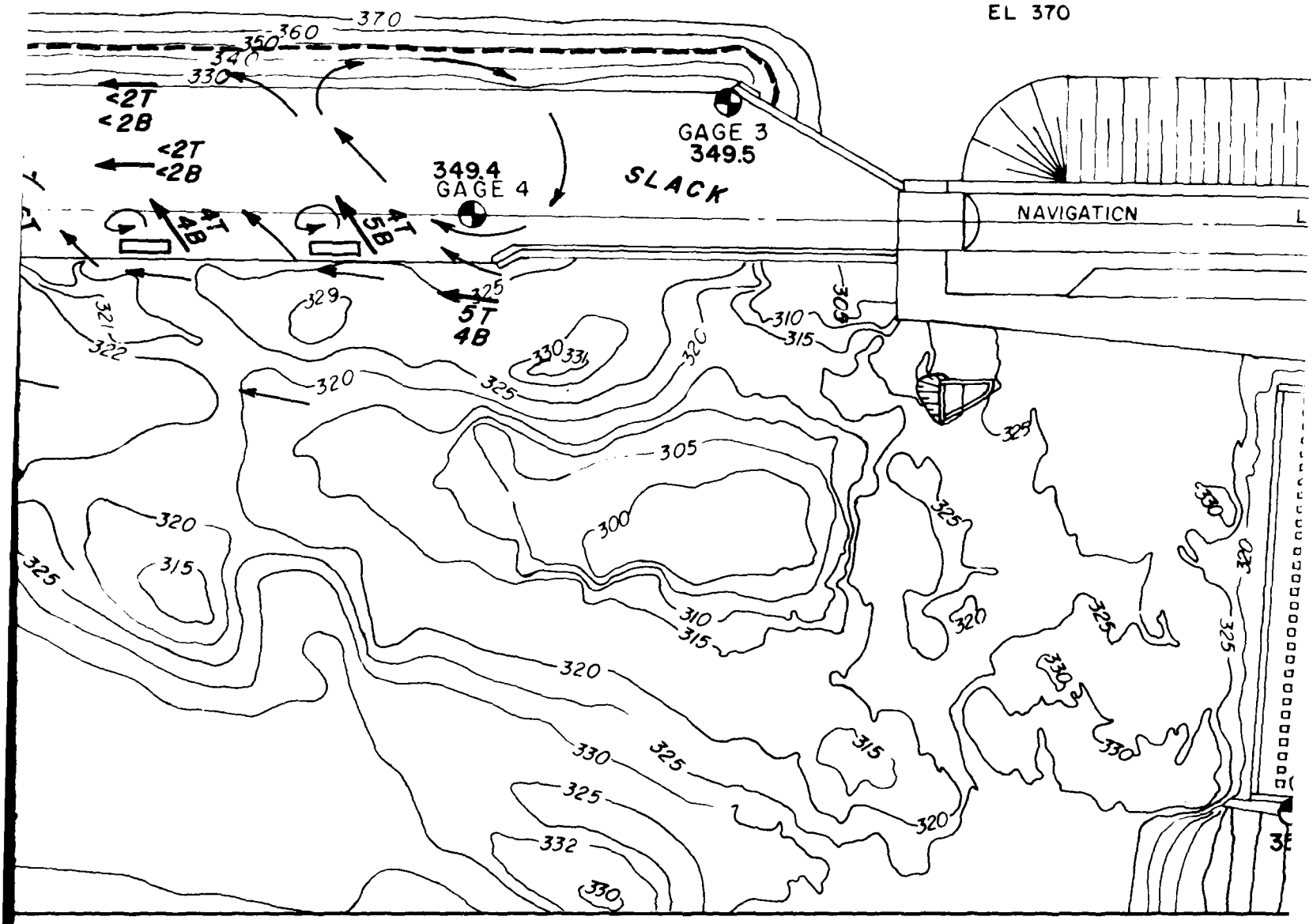
FLOW DISTR

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO

POWERHOUSE UNITS 4 TO

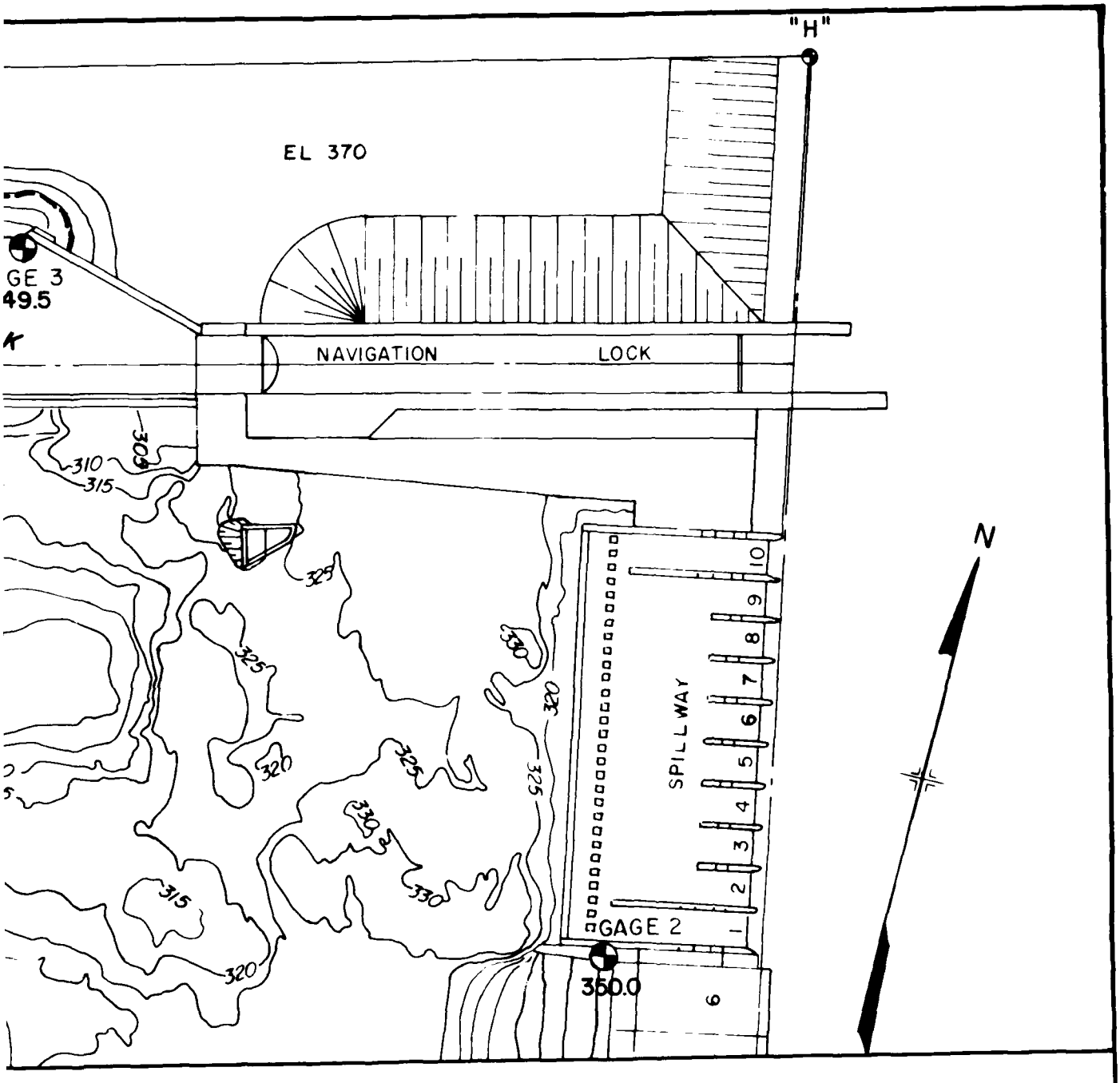
2



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000 CFS
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

THI

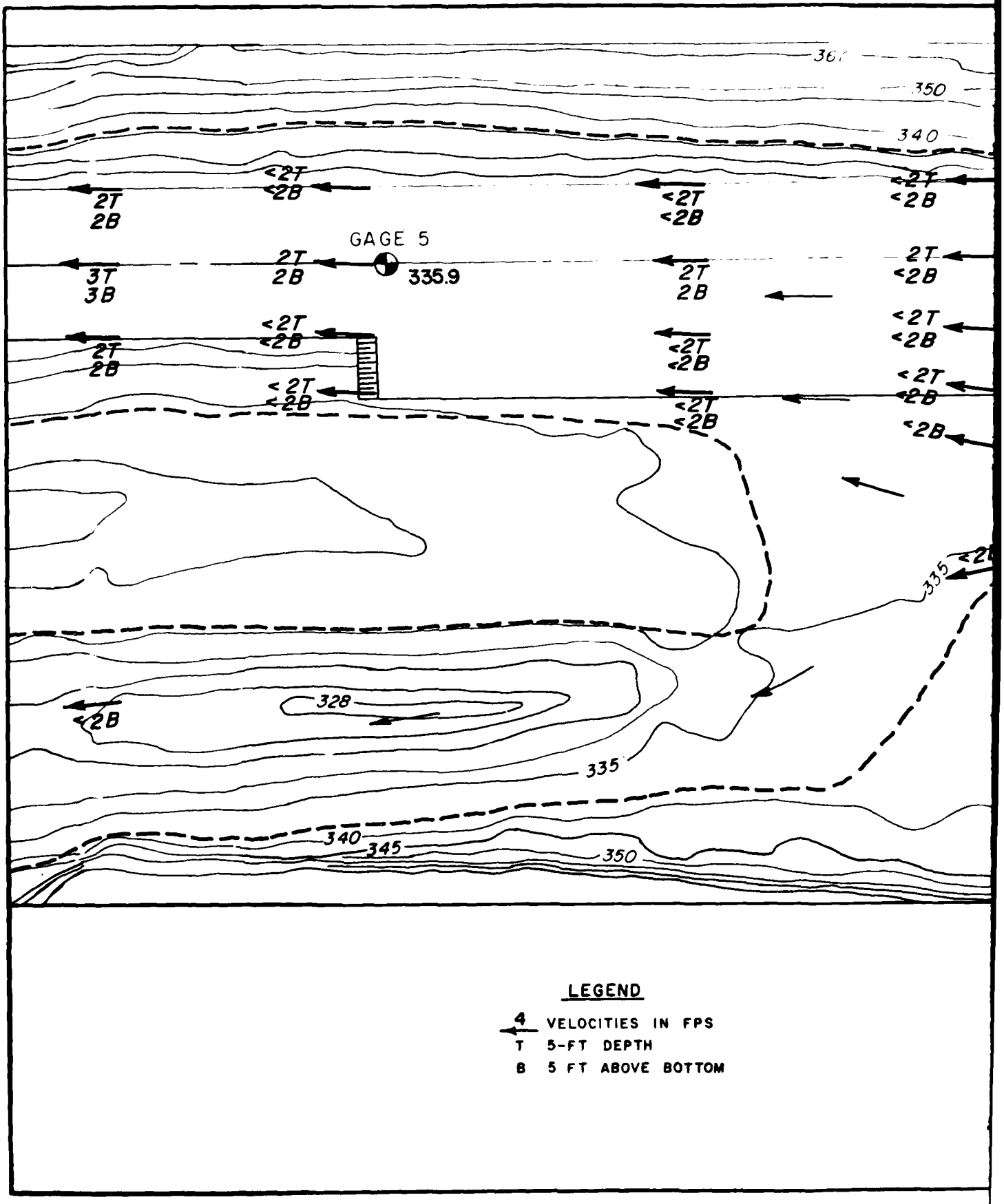


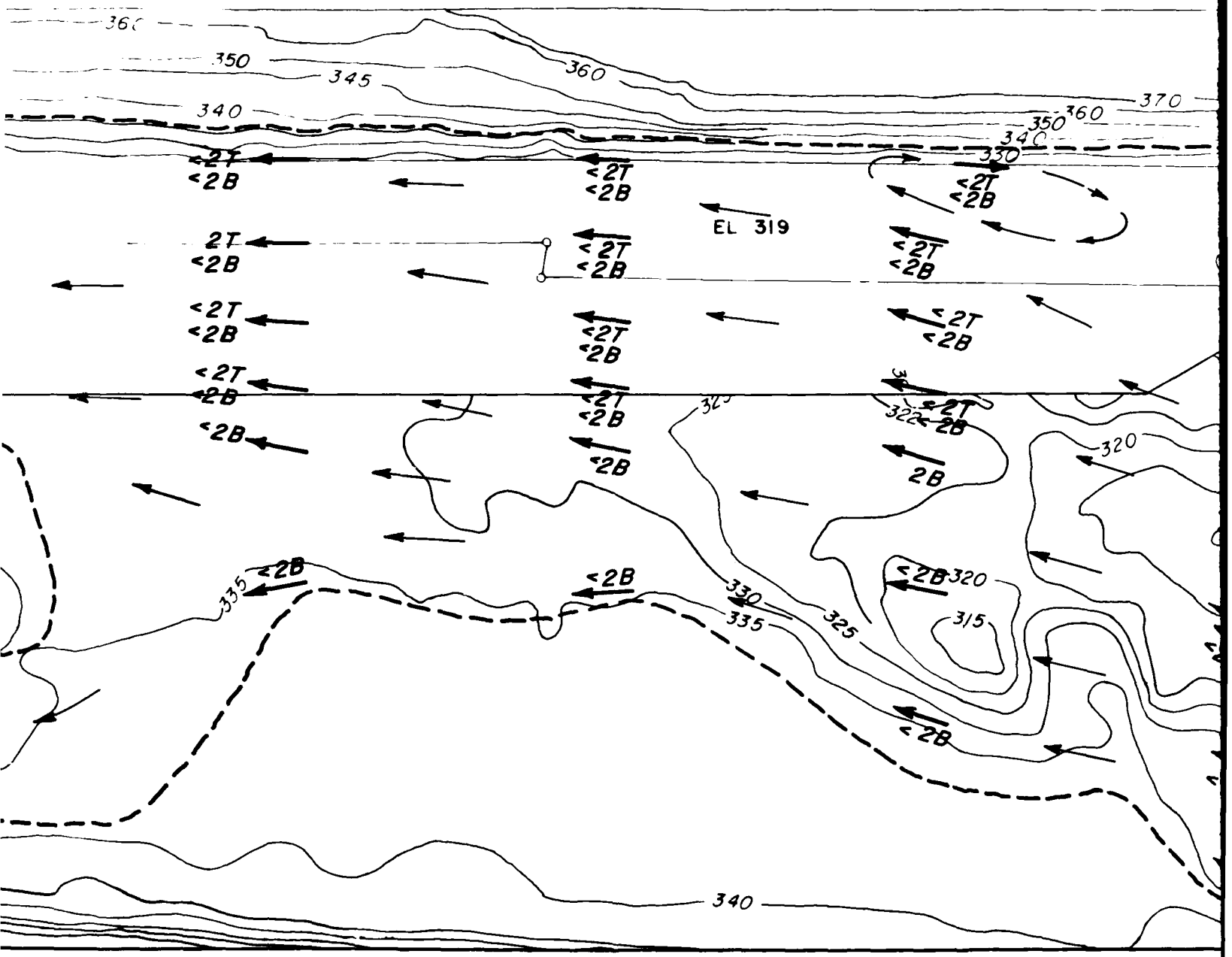
THREE 70-FT WALLS WITH 210-FT SPACING

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 34


350
340
<2T
<2B
2T
2B
GAGE 5
335.9
3T
3B
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

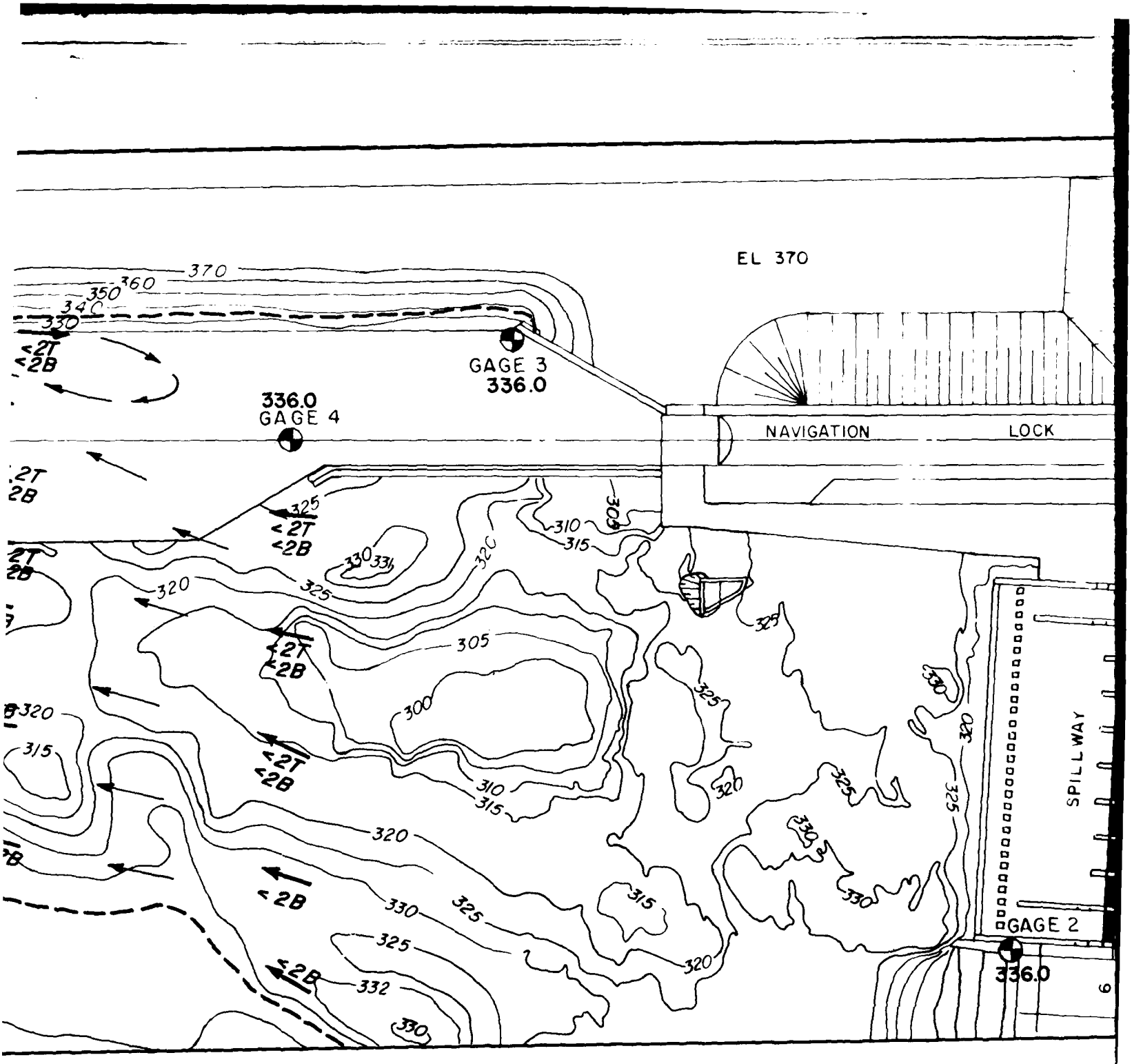
0 100 200 300 400 500 FT

FLOW DISTRI

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNIT 1

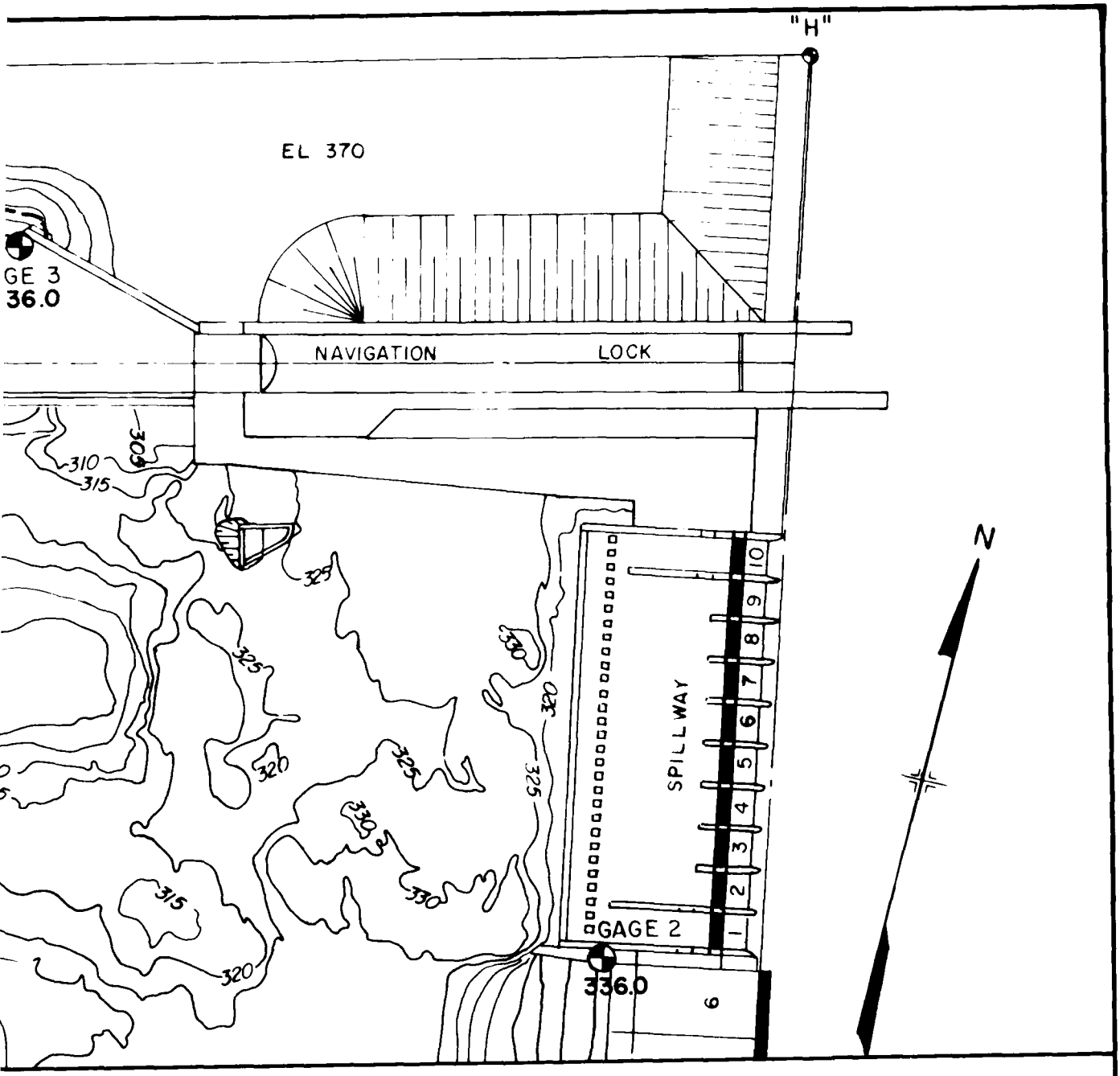
POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNIT 1	10 000 CFS
POWERHOUSE UNITS 4 TO 6	CLOSED

RIVE

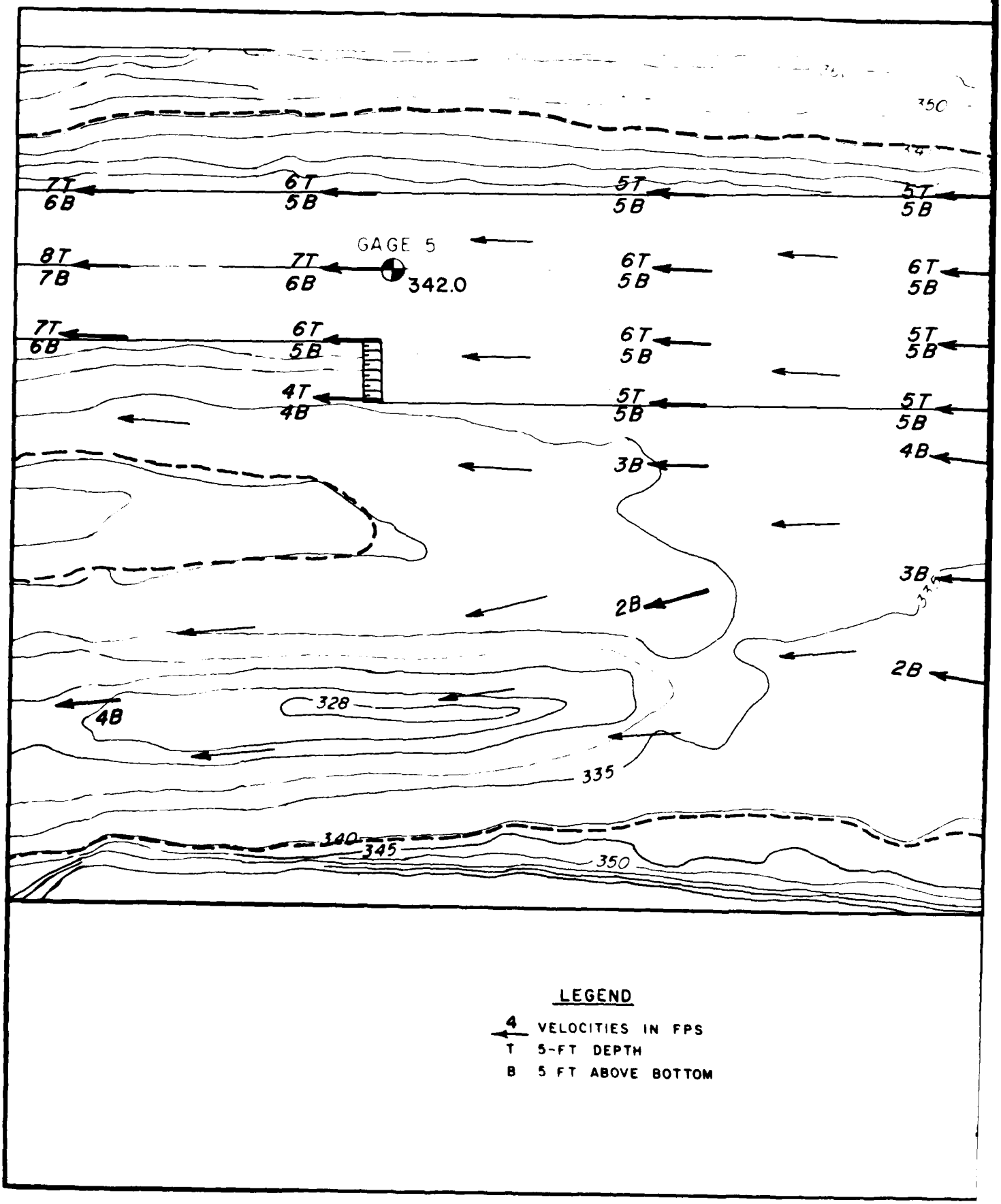


100-FT EXPANSION OF CHANNEL

FLOW CONDITIONS

RIVER DISCHARGE 10 000 CFS
McNARY POOL EL 335

PLATE 35


350
7T
6B
6T
5B
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5B
5T
5B
GAGE 5
342.0
8T
7B
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6B
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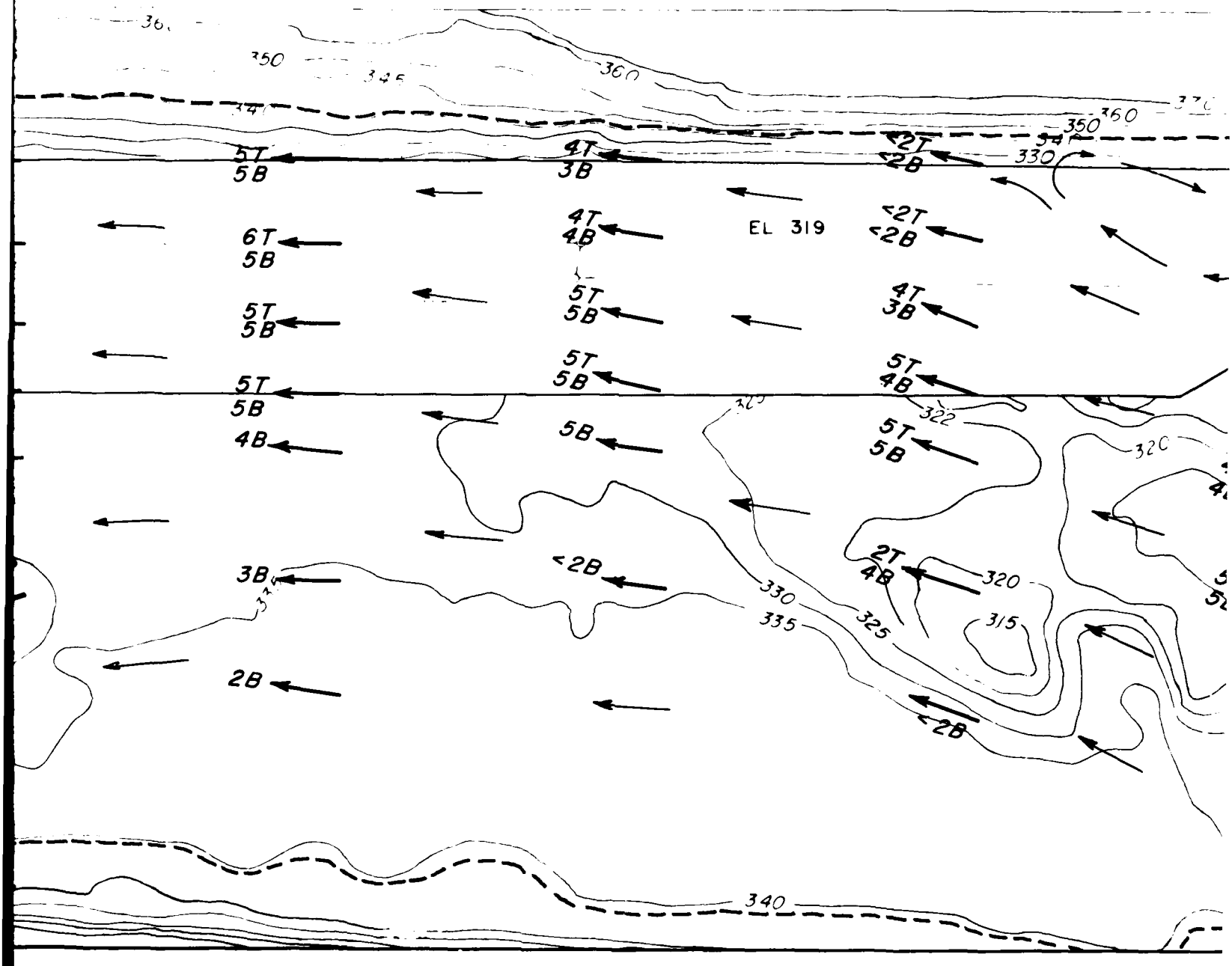
5B
5T
5B
4B
3B
3B
2B
2B
4B
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

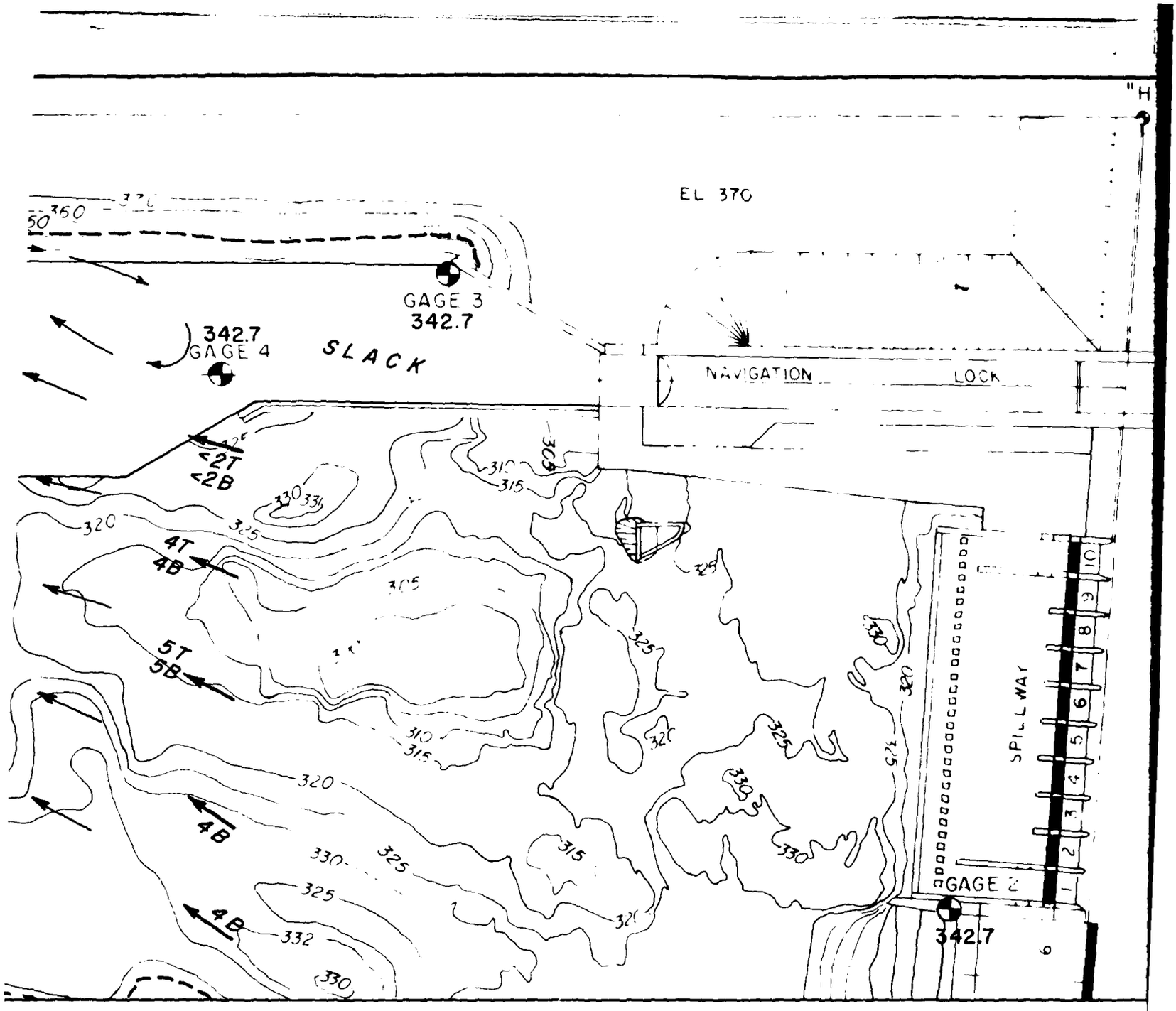
0 100 200 300 400 500 FT

FLOW DIST

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNIT 4



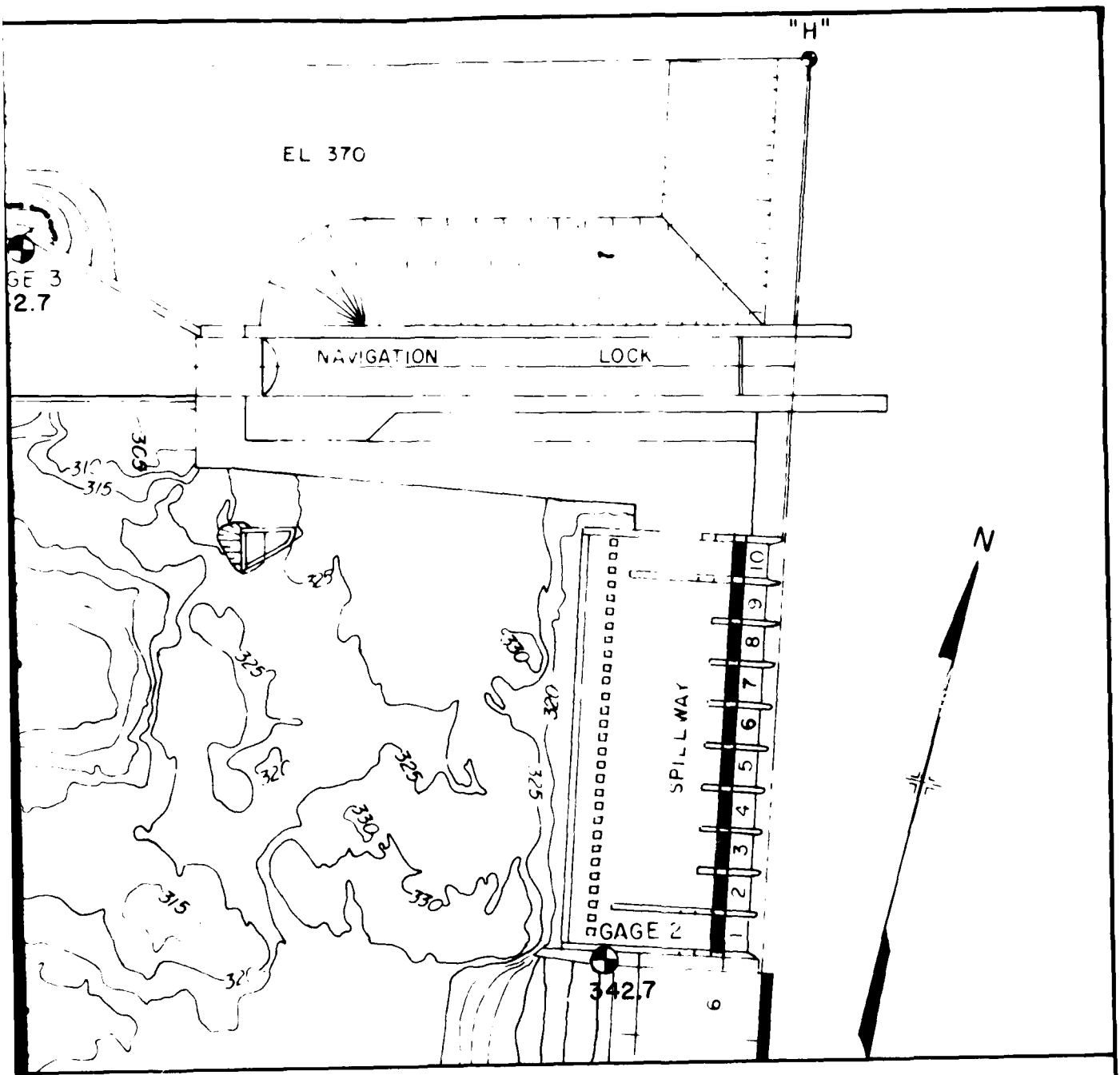
FLOW DISTRIBUTION

BAYS 1 TO 10	CLOSED
OUSE UNITS 1 TO 3	42 000 CFS
OUSE UNIT 4	18 000 CFS

100-FT EXPANSI

FLOW C

RIVER DISCHA
McNARY F

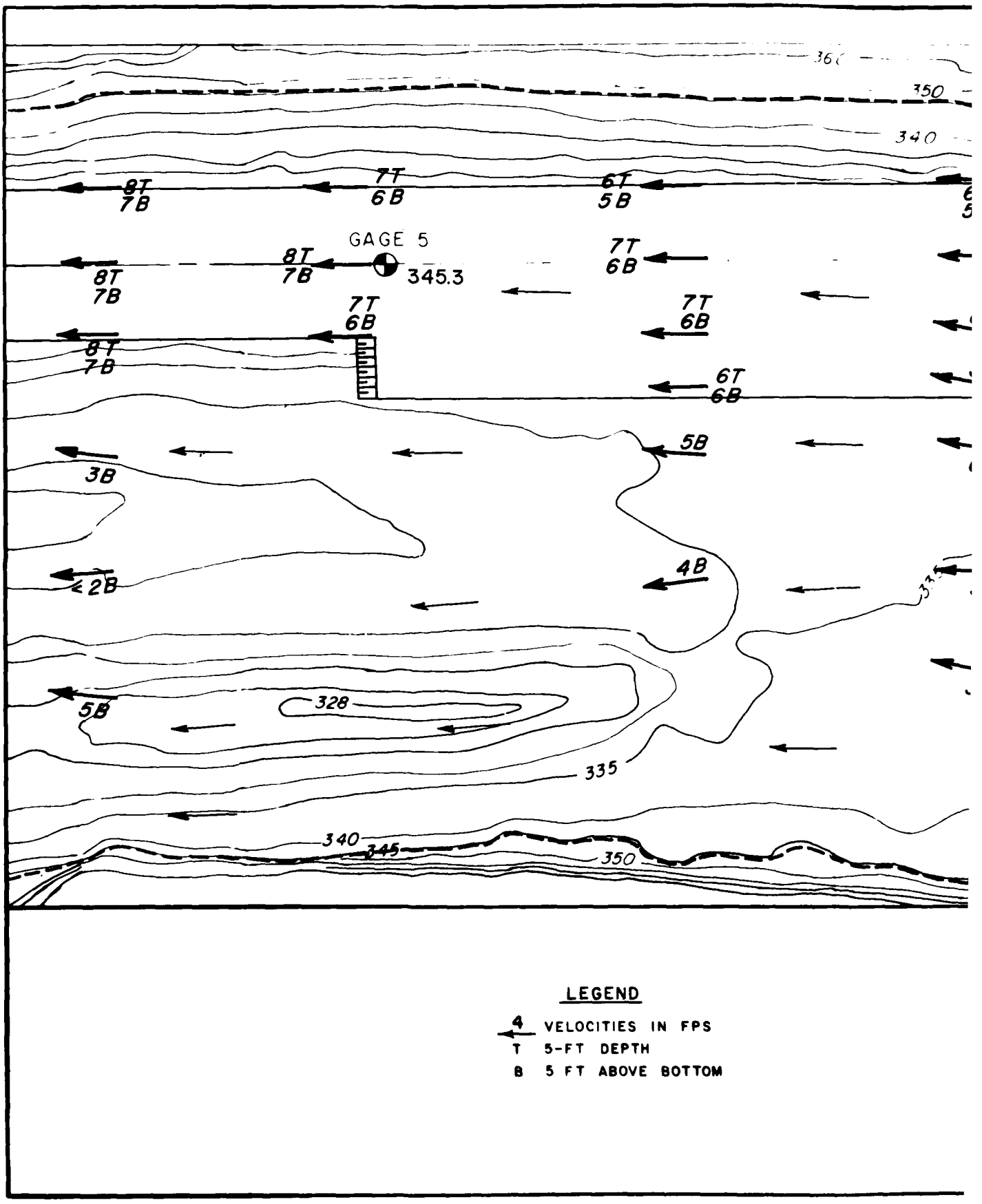


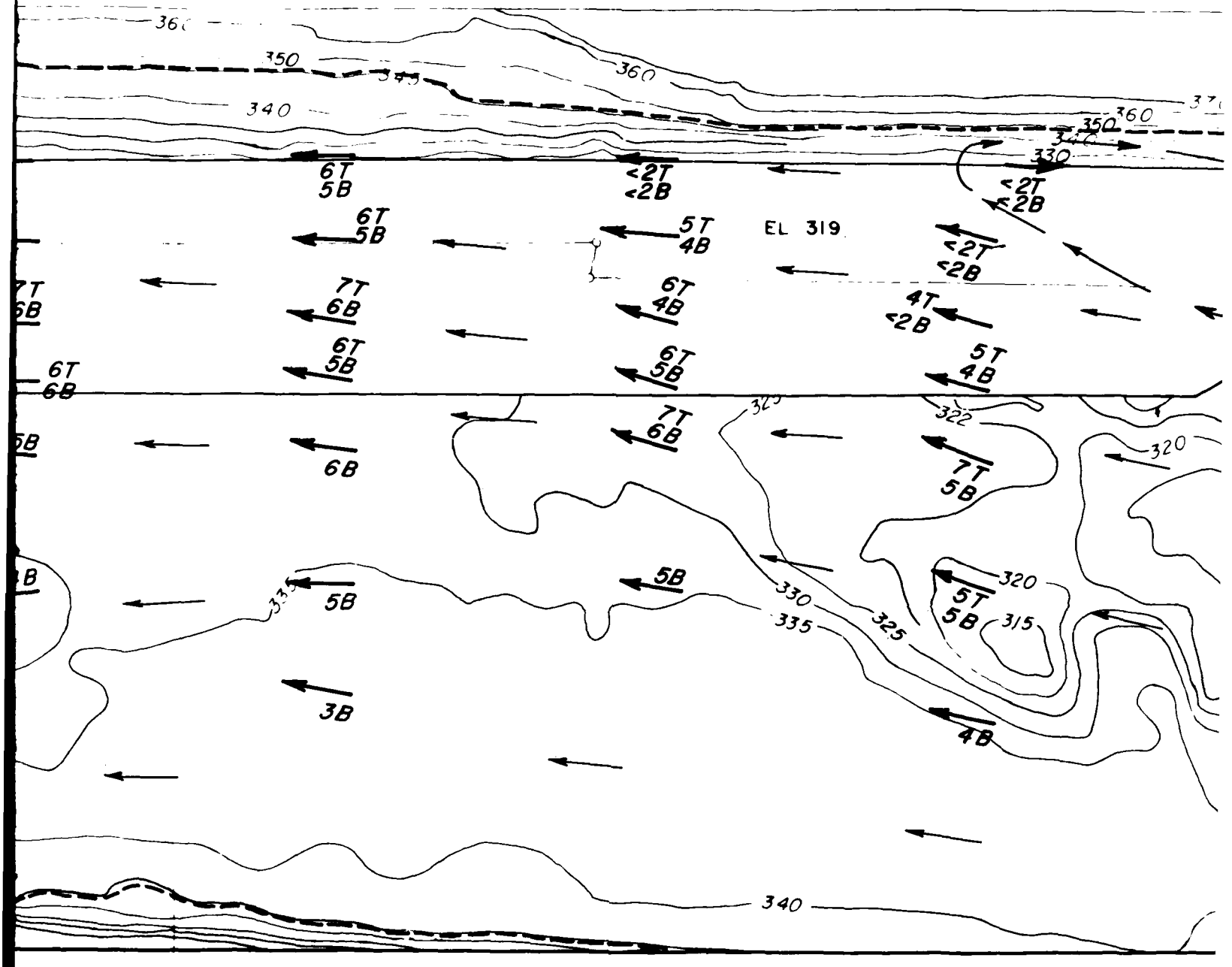
100-FT EXPANSION OF CHANNEL

FLOW CONDITIONS

RIVER DISCHARGE 60 000 CFS
McNARY POOL EL 335

PLATE 36


360
350
340
8T
7B
7T
6B
6T
5B
GAGE 5
345.3
3B
2B
4B
5B
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

0 100 200 300 400 500 FT

FLOW DI

PS

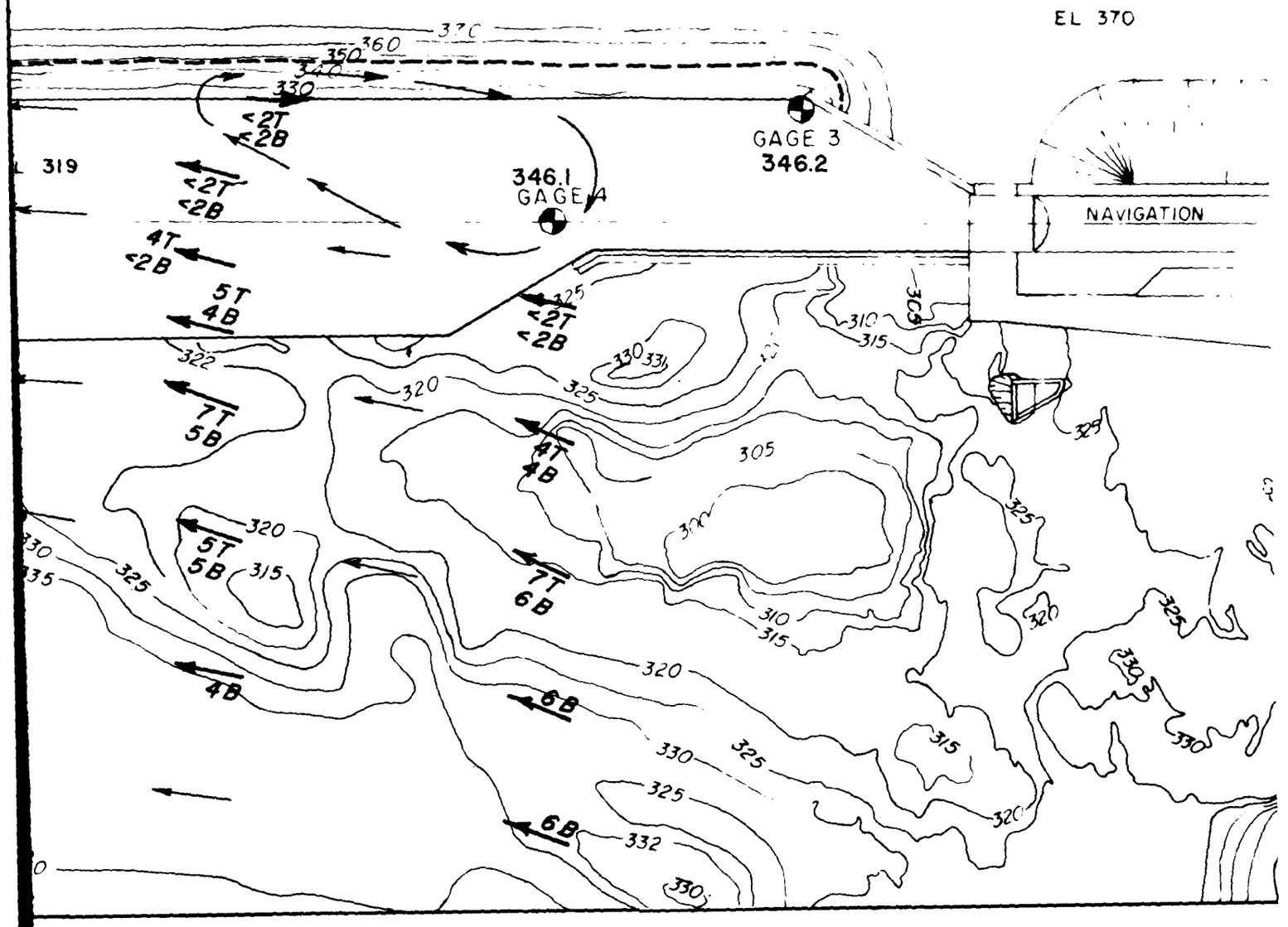
TOM

SPILLWAY BAYS 1 TO 10

POWERHOUSE UNITS 1 TC

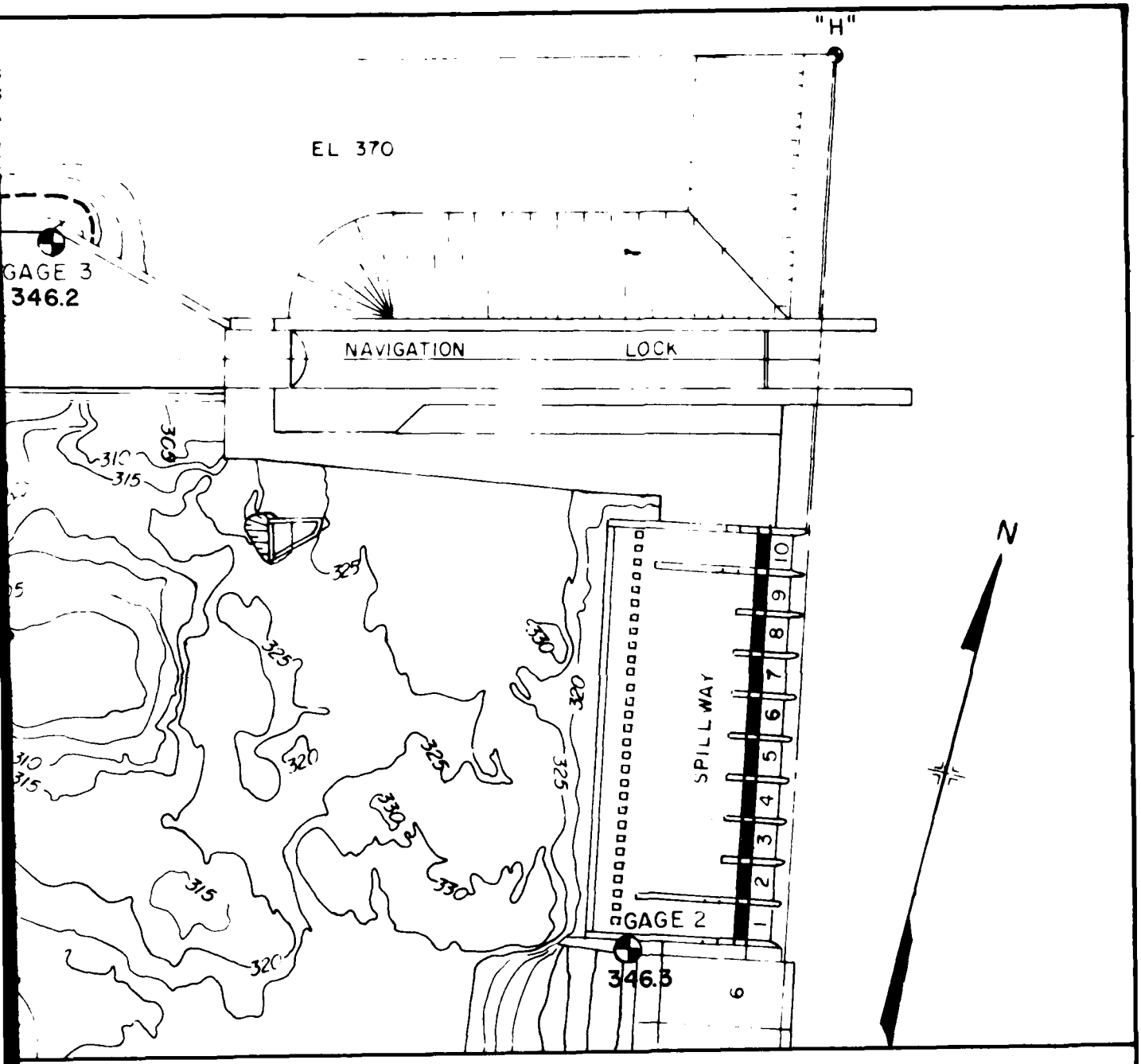
POWERHOUSE UNITS 4 TC

2



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	CLOSED
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS



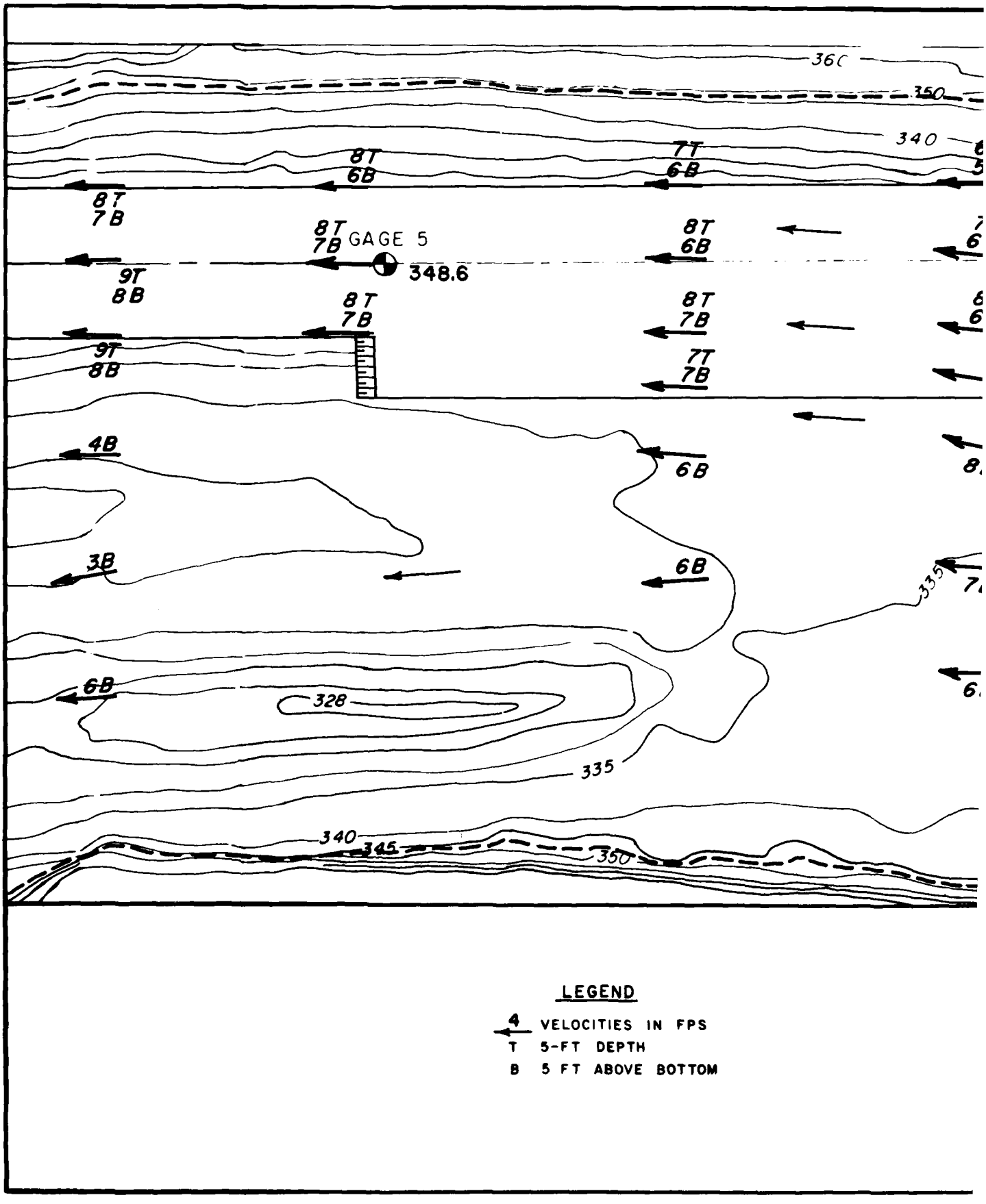
100-FT EXPANSION OF CHANNEL

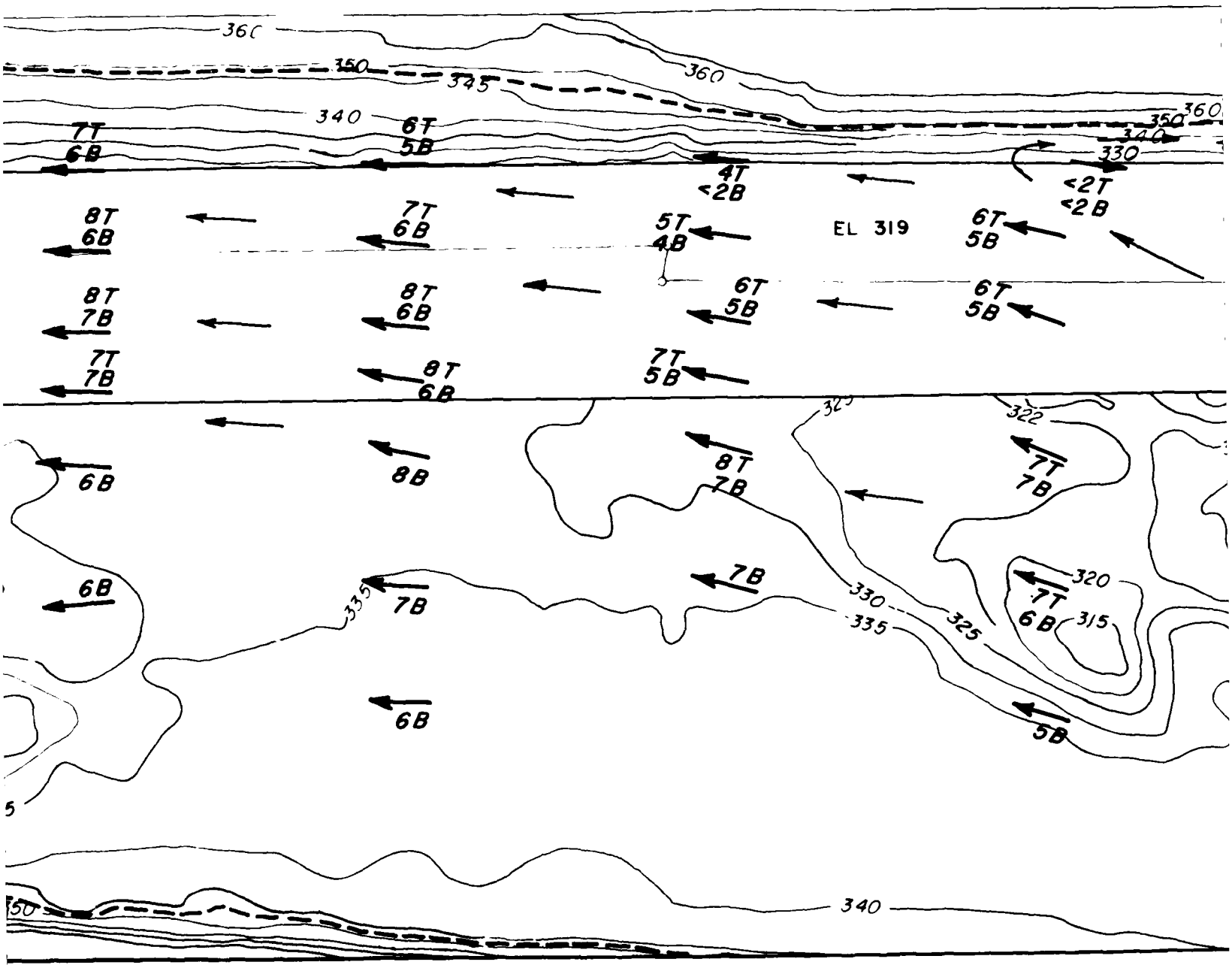
FLOW CONDITIONS

RIVER DISCHARGE 100 000 CFS
McNARY POOL EL 335

4

PLATE 37


360
350
340
8T
6B
7T
6B
8T
7B
8T
7B
GAGE 5
348.6
8T
6B
9T
8B
8T
7B
8T
7B
9T
8B
7T
7B
4B
6B
3B
6B
335
6B
328
335
340
345
350
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

0 100 200 300 400 500 FT

END

IES IN FPS

EPTH

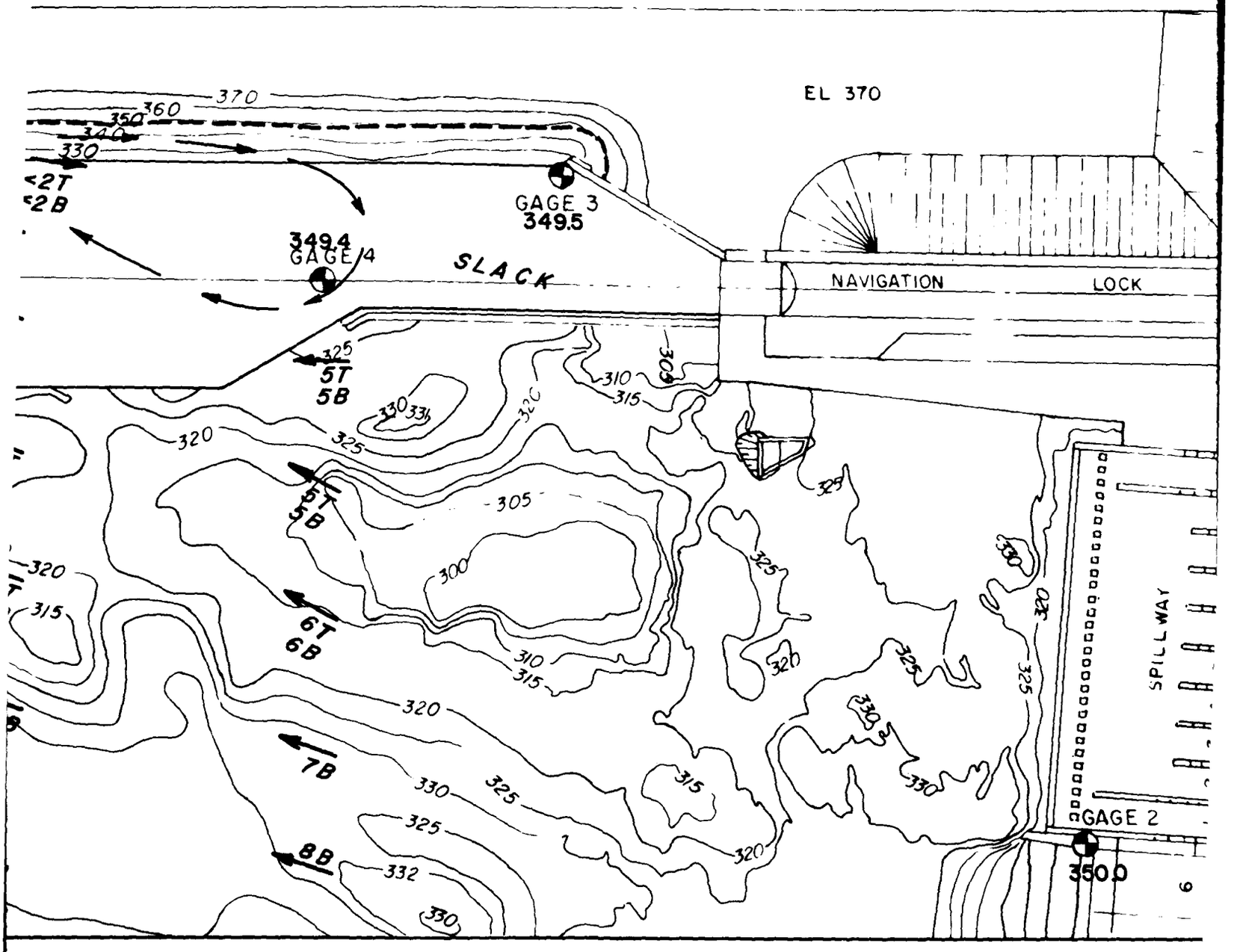
BOVE BOTTOM

FL

SPILLWAY BAYS

POWERHOUSE UNI

POWERHOUSE UNI

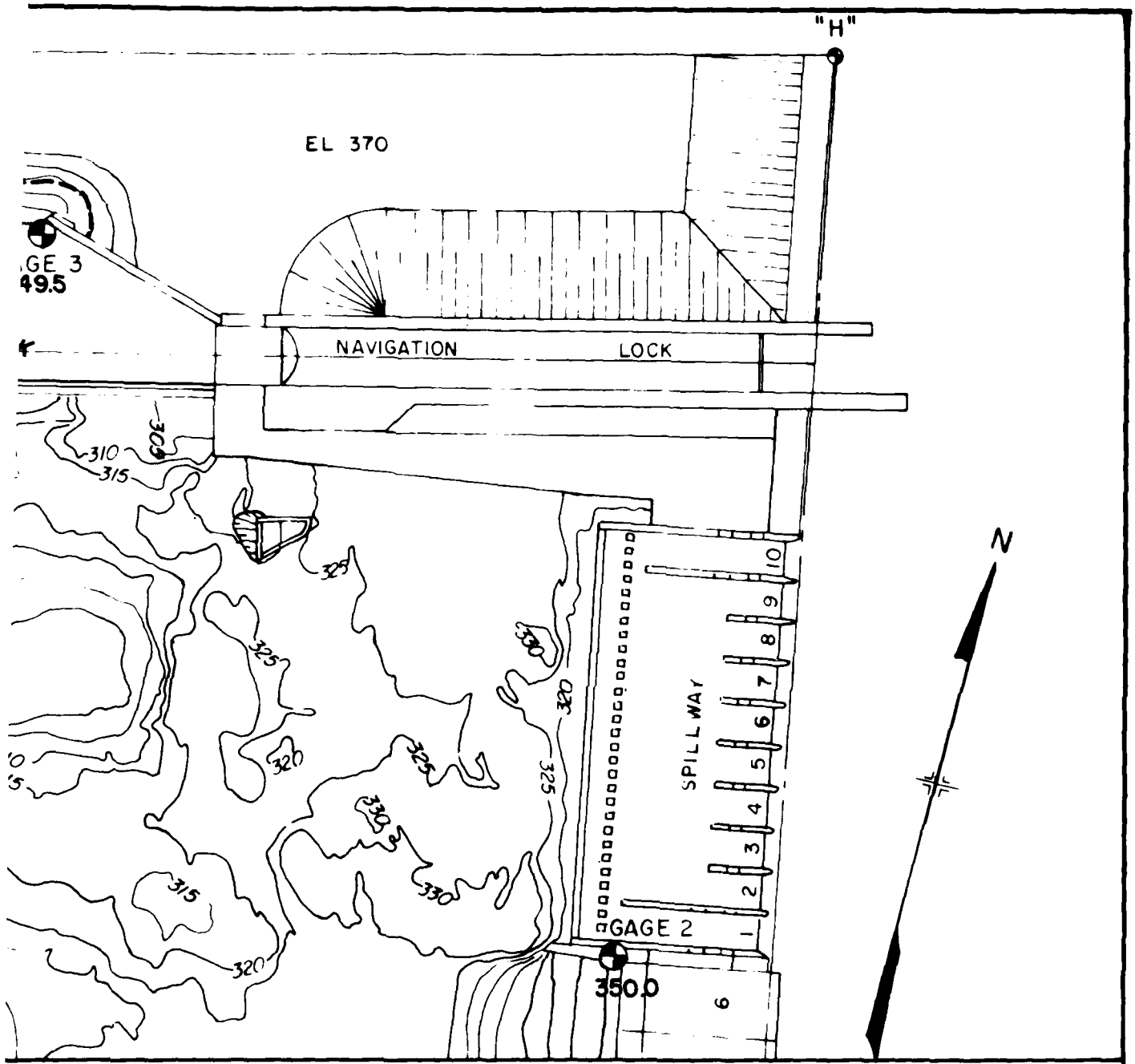


FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	50 000 CFS
POWERHOUSE UNITS 1 TO 3	43 300 CFS
POWERHOUSE UNITS 4 TO 6	56 700 CFS

100-FT

RIVE
N

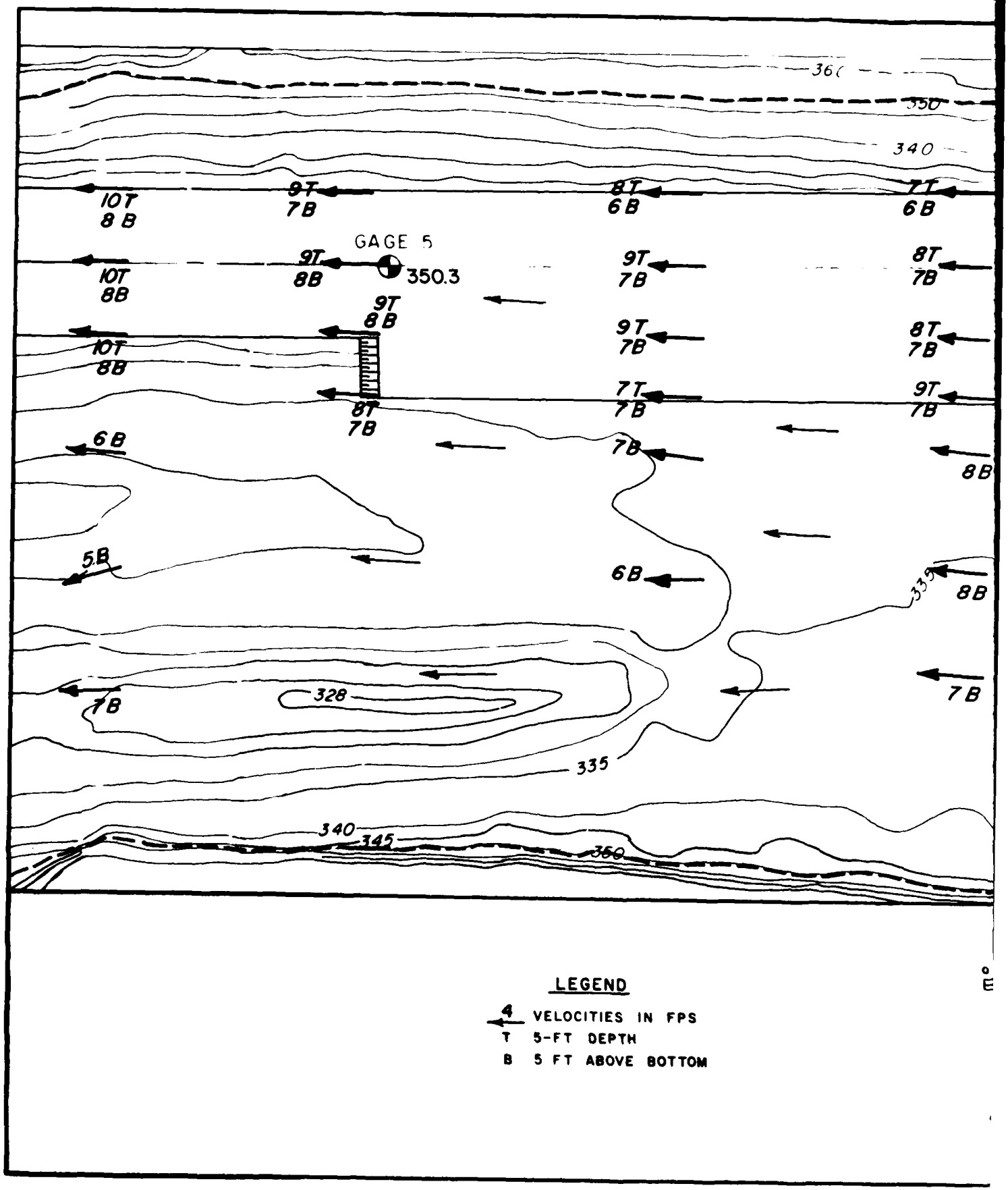


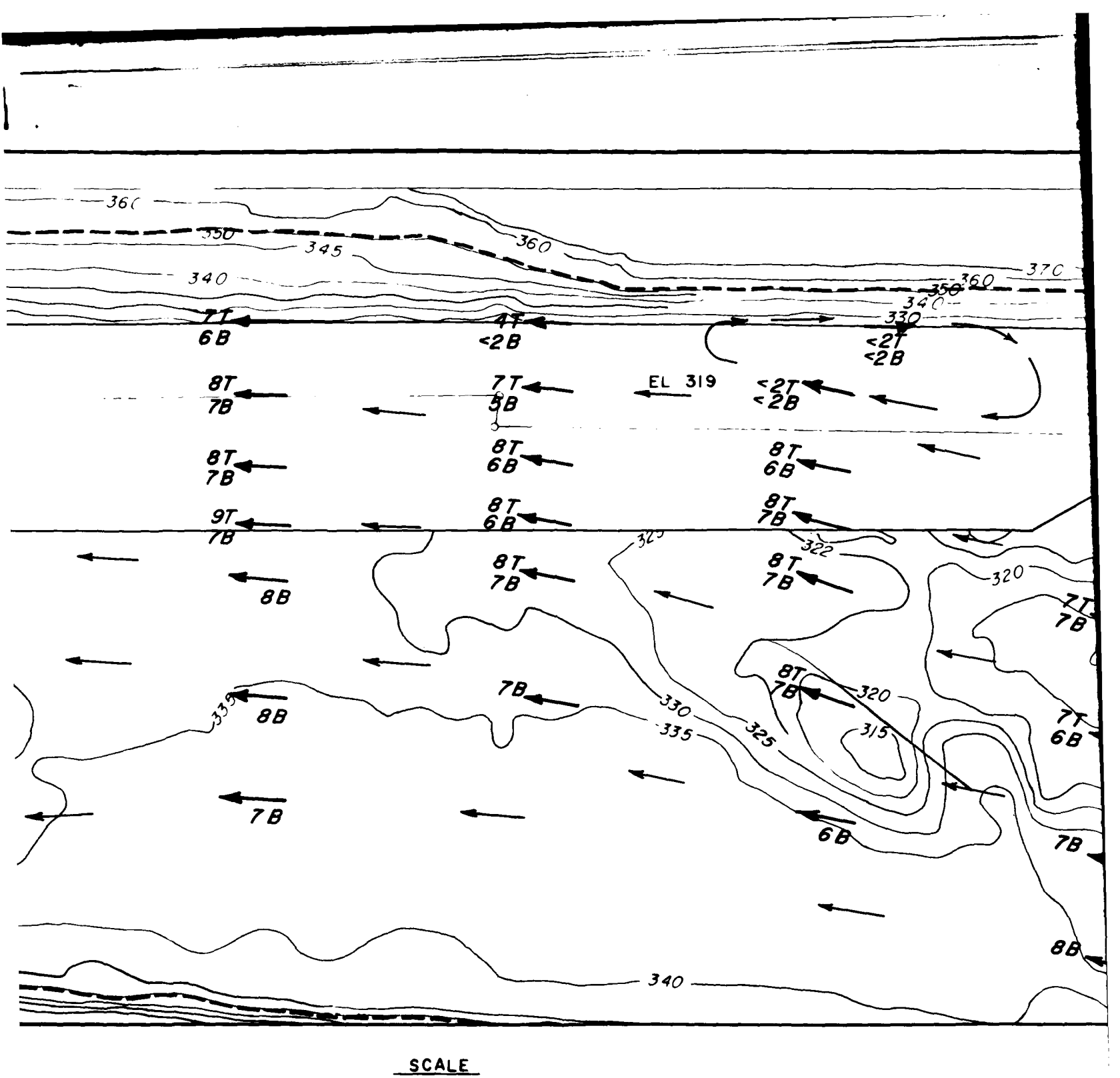
100-FT EXPANSION OF CHANNEL

FLOW CONDITIONS

RIVER DISCHARGE 150 000 CFS
McNARY POOL EL 335

PLATE 38


360
350
340
10T
8 B
9T
7B
8T
6B
7T
6B
GAGE 5
9T
8B
350.3
9T
7B
8T
7B
10T
8B
9T
8B
9T
7B
8T
7B
10T
8B
7T
7B
9T
7B
8T
7B
6B
7B
8B
5B
6B
339
8B
328
7B
7B
335
340
345
360
LEGEND
4 VELOCITIES IN FPS
T 5-FT DEPTH
B 5 FT ABOVE BOTTOM



SCALE

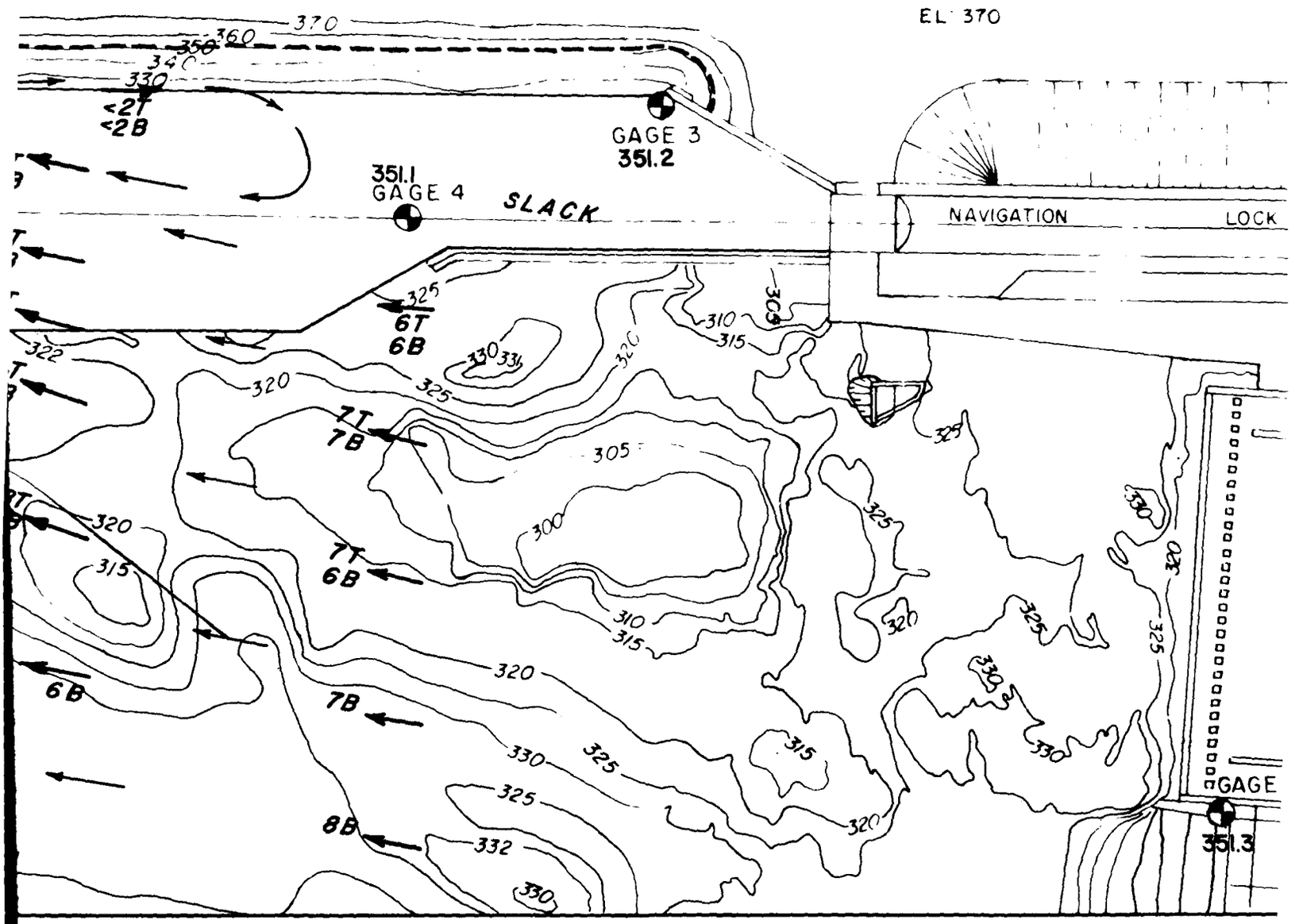
0 100 200 300 400 500 FT

FLOW DISTRIBU

SPILLWAY BAYS 1 TO 10

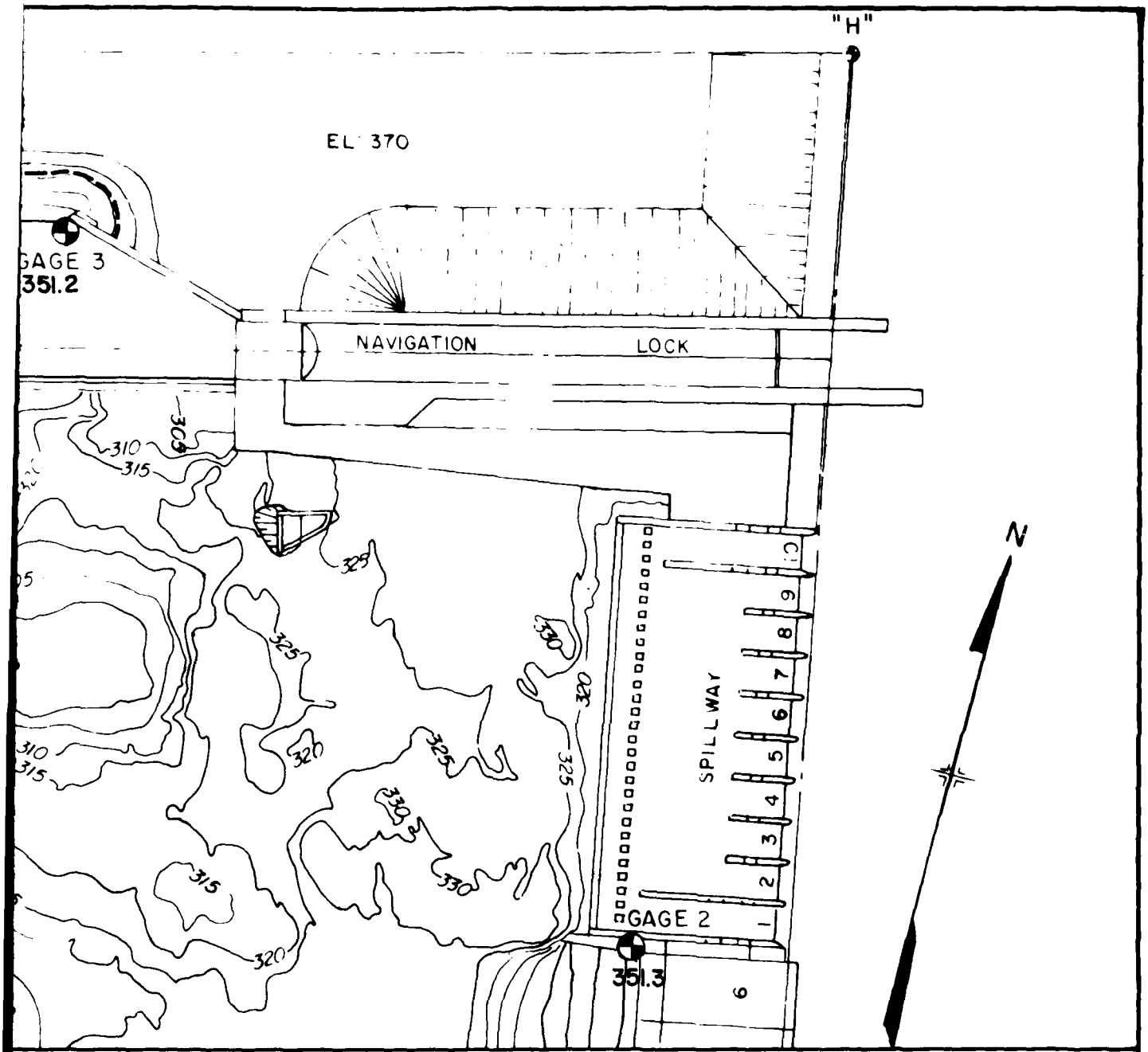
POWERHOUSE UNITS 1 TO 3

POWERHOUSE UNITS 4 TO 6



FLOW DISTRIBUTION

SPILLWAY BAYS 1 TO 10	79 500 CFS
POWERHOUSE UNITS 1 TO 3	44 400 CFS
POWERHOUSE UNITS 4 TO 6	56 100 CFS



100-FT EXPANSION OF CHANNEL

FLOW CONDITIONS

RIVER DISCHARGE 180 000 CFS
McNARY POOL EL 335

PLATE 39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LMED